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FIFTH BILLINGS SYMPOSIUM

ON

DISTURBED LAND REHABILITATION

Volume III:

Billings, Montana
March 25-30, 1990

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FIFTH BILLINGS SYMPOSIUM

ON

DISTURBED LAND REHABILITATION

Volume III

Billings Plaza Holiday Inn, Billings, Montana
March 25-30, 1990

CO-CHAIRMEN

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DISCLAIMER

This publication contains the proceedings of the Symposium on Disturbed Land Rehabilitation. Speakers were asked to submit camera-ready copy for this publication. Because of the schedule for printing, the chairmen were unable to edit the texts and apologize for any errors in the copy or poor reproduction of figures or tables.

Several papers were not received in time to be included in this publication; thus, the lack of conformity between the Agenda of the Symposium and this published proceedings was unavoidable.

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Planning, Rehabilitation, and Treatment of Disturbed Lands
Billings Symposium, 1990

HABITAT RESTORATION ON NAVAL PETROLEUM RESERVES IN KERN COUNTY, CALIFORNIA

B.C. Anderson[1]

ABSTRACT

One of several tasks performed under contract to the Department of Energy (DOE) by EG & G Energy Measurements as part of the endangered species program is the restoration of abandoned well pads, roads, pipelines and soil borrow sites resulting from oil and gas production activities on Naval Petroleum Reserves in California (NPRC). Naval Petroleum Reserves in California is located in the Elk Hills approximately 30 miles southwest of Bakersfield in the rain shadow of the coastal ranges. Annual precipitation is approximately five inches. Reclamation of disturbed habitat on NPRC began with research plots and test trials in the early 1980s. Full scale reclamation began in 1985 and has continued through the 1989 planting season. Almost 700 acres have been revegetated, which represents over 1,200 sites distributed over the 47,250 acres of NPRC and averaging less than .75 acre in size. Monitoring of the sites began in 1987 to establish reclamation success and evaluate reclamation techniques. Reclamation objectives include the improvement of wildlife habitat for four endangered species living on NPRC, and the protection of the soils from wind and water erosion on the disturbed sites.

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[1] EG & G Energy Measurements, Inc., Applied Ecology Department, P.O. Box 127, Tupman, CA 93276.

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Planning, Rehabilitation, and Treatment of Disturbed Lands
Billings Symposium, 1990

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INTRODUCTION

Description of Elk Hills[1]

The Department of Energy's (DOE) Naval Petroleum Reserve No. 1 (NPR-1) is located in southwestern Kern County, California approximately 30 miles southwest of Bakersfield (Figure 1). Naval Petroleum Reserve No. 1 encloses most of the Elk Hills which are low foothills of the higher Temblor Range to the west. Elk Hills lies in the rain shadow of the coastal mountains. Mean annual precipitation at Bakersfield, 30 miles northeast of Elk Hills, is 5.72 inches, at Buttonwillow about four miles north and in the valley floor, it averages 5.02 inches, and at Taft directly south and at a similar elevation, it averages 4.88 inches. One year in 20, precipitation can be as low as two inches or as high as eight inches. Mean annual precipitation on Elk Hills based on data recorded at NPRC since 1981 is 4.73 inches. About 85% of the precipitation falls between November and April. Rainfall is usually relatively gentle, and individual storms in this area can bring highly variable amounts of precipitation over different parts of Elk Hills.

Temperatures are mild throughout the year. The mean maximum annual temperature is 78° F, and the mean minimum temperature is 52° F. Summers are hot and dry; mean maximum temperature is 95° F and mean minimum temperature is 65° F for June through September. Temperatures of 100° F and higher, with records of 115° F, are commonly recorded in July and August. From November through February, mean maximum temperature is 62° F and mean minimum temperature is 40° F.

The Elk Hills consist of gently rounded slopes with narrow divides and an intricate system of highly dissected draws and dry stream channels (Woodring et al. 1932). Surface soils are typically sandy loams or loams, especially where there is a well-developed vegetative cover.

Elk Hills vegetation is part of a very broad type called Valley Grassland (Heady 1977) that surrounds the agricultural land of the Central Valley. In its pristine condition, much of the Valley Grassland probably consisted of perennial bunchgrasses and an overstory of shrubs, but European plant introductions and livestock grazing converted almost all of it to an annual grassland in the mid to late 19th century. Elk Hills' dominant ground cover species, red brome or foxtail chess (*Bromus rubens* L.) and red-stemmed filaree (*Erodium cicutarium* (L.) L'Her.') were aggressive, introduced annuals that effectively displaced native species. Few of the introduced European annuals were present on Elk Hills 150

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[1] The description of Elk Hills is taken from O'Farrell and Mitchell 1985.

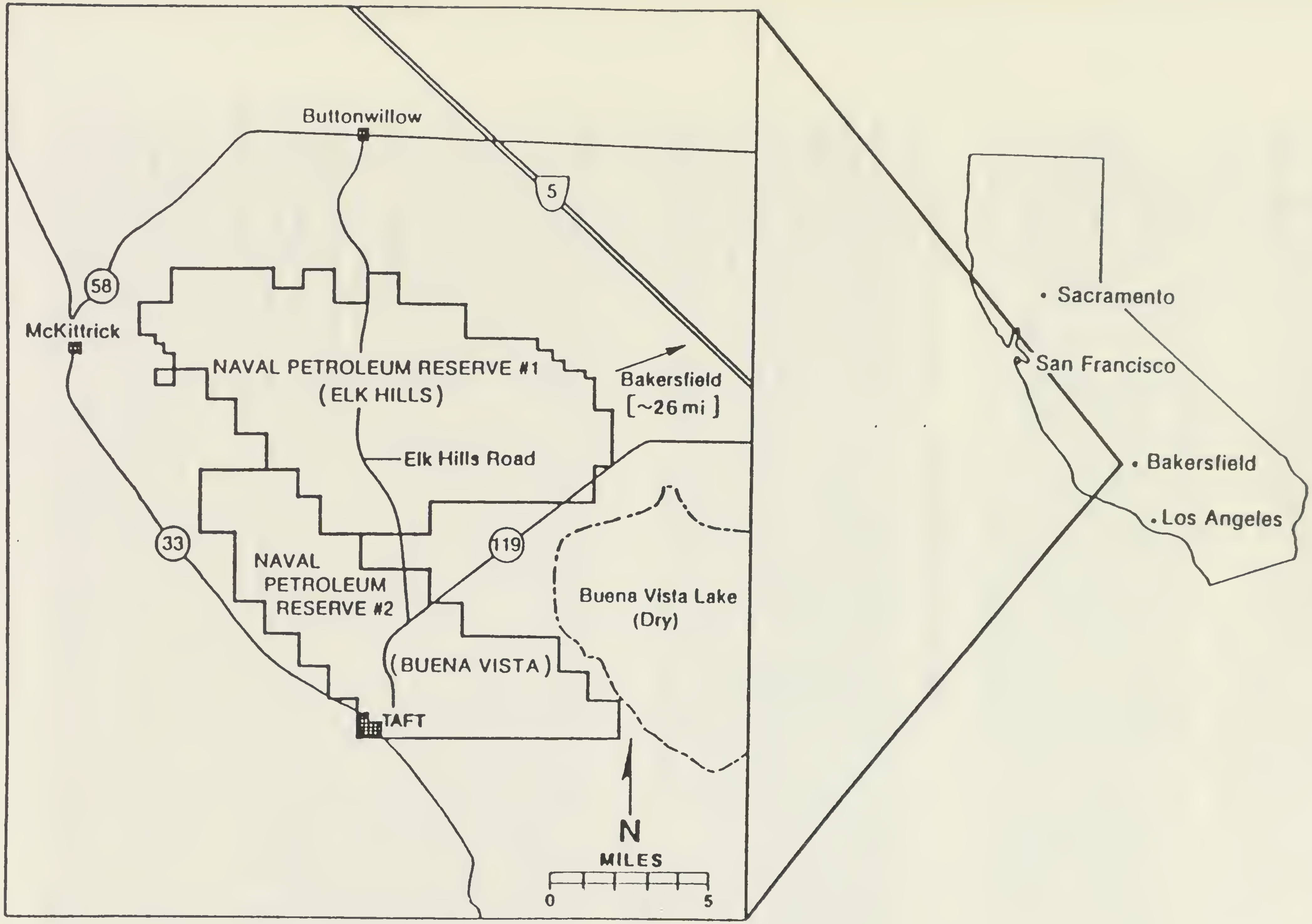

Figure 1. Location of Naval Petroleum Reserves No. 1 and No. 2, Kern County, California.

to 200 years ago. Because of low average annual precipitation, perennial bunchgrasses probably were never a very important part of the ground cover either (Twisselman 1967; Heady 1977). Whatever the pre-European condition of vegetation on Elk Hills, introduced annuals, red brome and filaree unquestionably dominate the ground cover now.

The most common shrub is desert saltbush (*Atriplex polycarpa* (Torr.) Wats.) which is scattered throughout the herbaceous annuals and is especially dense in disturbed areas such as along roadsides and edges of well pads. Other locally common shrubs include: bladderpod (*Isomeris arborea* Nutt.), cheesebush (*Hymenoclea salsola* T. & G.), spiny saltbush (*Atriplex spinifera* Macbr.), matchweed (*Gutierrezia bracteata* Abrams), winterfat (*Ceratoides lanata* (Pursh) J.T. Howell), and buckwheat (*Erigonum fasciculatum*).

History of Reclamation

Drilling and petroleum production began in the early 1900s on NPR-1. However, in 1976 a new intensive program of production at maximum efficient rate (MER) was mandated by Public Law 94-258 to increase national oil production (U.S. Dept. of Energy 1979). Pipelines were greatly expanded, and a gas separation and compression plant, bulk storage facilities, water flood injection system, pumper electrification network, cathodic protection system, and related new facilities were built. When MER is completed, the amount of land disturbed will equal the amount developed between 1919 and 1976 (U.S. Fish and Wildlife Service 1980).

On June 15, 1979 the Secretary of the Interior, through the regional office of the U.S. Fish and Wildlife Service (FWS), notified DOE that construction activities on Elk Hills required a formal consultation owing to their potential impacts on two endangered species, the San Joaquin kit fox (*Vulpes macrotis mutica*) and blunt-nosed leopard lizard (*Gambelia silus*) (U.S. Fish and Wildlife Service 1979). Since that time, two other species of animals the giant kangaroo rat (*Dipodomys ingens*), and Tipton's kangaroo rat (*Dipodomys nitratoides*) have been listed as endangered and one plant Hoover's wooly-star (*Eriastrum hooveri*) has been listed as threatened. All species occur on Elk Hills and are protected under the Endangered Species Act of 1973 (P.L. 93-205) which requires federal departments and agencies to carry out programs for the conservation of endangered species on their lands, and to insure that their actions do not jeopardize the continued existence of such endangered species or result in the destruction or modification of habitat of such species which is determined by the Secretary of Interior to be critical. In October 1979, formal consultation with the FWS was initiated. The FWS concluded that the overall impacts anticipated on Elk Hills may jeopardize the continued existence of the San Joaquin kit fox; blunt-nosed leopard lizard, and their critical habitats (U.S. Fish and Wildlife Service 1980).

In their Biological Opinion, FWS proposed reasonable and prudent alternatives to avoid jeopardy to both species, while allowing DOE activities to continue concurrently with mitigation (U.S. Fish and Wildlife Service, 1980). These alternatives included a plan for the restoration of disturbed lands on NPRC or a DOE commitment to compensate or mitigate the impacts of MER on endangered species and their habitats.

The task of restoration of disturbed lands at NPR-1 presents some unique challenges. Soils have eroded over the years, resulting in the reduction of the amount of topsoil present or, where extreme erosion has occurred, exposure of underlying layers of soils high in salts, which were deposited when the area was part of the surrounding basin system. The leaching process is slow with the low annual rainfall and desiccating summer temperatures.

Further disturbance of these soils by oil and gas development activities creates even more obstacles when considering restoration. Steep cut-and-fill slopes are created as new wells are developed, historical disturbances are generally characterized by compacted soils and may be contaminated from drilling chemicals/substances that were used in early drilling processes (O'Farrell and Mitchell 1985). Each alteration to the natural conditions complicates the methodology for returning the disturbed sites to "preexisting conditions".

Early attempts to reclaim disturbed lands on NPR were "rarely ... successful" and statements were made that if success is to be achieved, it would be with supplemental watering (U.D. Department of Energy 1979). This philosophy lead to the conclusion in the 1979 Environmental Impact Statement that one of the unavoidable effects of MER would be the loss of habitat. These early statements became a challenge rather than a deterrent for the habitat restoration program at NPRC. In the fall of 1981, several field trials were initiated to 1) test species adapted to conditions on Elk Hills, 2) evaluate reclamation technologies and determine which are best adapted to Elk Hills, 3) evaluate the use of native seed sources on Elk Hills, and 4) evaluate reclamation equipment needs for the rather unique conditions that exist in an active oil and gas field (O'Farrell and Mitchell 1985). Reclamation was carried out at a research level for the next three years. The results of the research effort lead to a large scale reclamation program which began in 1985 and has continued to the present day. Approximately 700 acres have been revegetated during this period, which represent over 1,200 different sites located throughout the 47, 245 acres of NPR-1.

INVENTORY OF POTENTIAL RECLAMATION SITES ON NPR-1

Inventory of Disturbed Parcels of Land

Prerequisite to all tasks associated with the reclamation of disturbed lands was the completion of an inventory of disturbances on NPR-1. This need was reinforced in the terms and conditions of the FWS's second Biological Opinion rendered in 1987 (U.S. Fish and Wildlife 1987). It reiterated that the completion of "an inventory and listing of previously disturbed parcels and acreages at Elk Hills" would be a key part of the rehabilitation of disturbed lands on NPR-1 to offset loss of endangered species habitats.

Prior to the spring of 1989 the location of disturbed parcels of land on NPR-1 was unknown. Selection of sites for reclamation was made from field reconnaissances, which proved to be very time consuming and incomplete. During 1988, EG & G Energy Measurements, Inc. was tasked by DOE to inventory all parcels of land on NPR-1 and determine the location and extent of land disturbances. Through the use of aerial photography taken during the summer of 1988 and state-of-the-art mapping techniques, disturbances on NPR-1 were mapped and categorized by type of disturbance. This information was entered into an automated geographic information system (GIS) and map products and tabular summaries were generated.

Disturbances were broken down into types of disturbance associated with typical oil and gas production activities; well pads, sumps, roads, pipelines, borrow or scraped areas, diked washes, firebreak, landfill or waste sites, major roads, pipeline rights-of-way, facilities, and some office or historic residential areas. The total number of acres disturbed was determined to be 6,968 acres, approximately 17% of the total acreage within NPR-1 boundaries. Since NPR-1 is an active oil field, producing over 100,000 barrels of oil daily, many of the sites identified as disturbed are in use. Of the acreage reported as disturbed, only about 700 can be reclaimed at this time. A major and more comprehensive reclamation effort will take place when oil and gas production ceases and NPR-1 is abandoned.

HABITAT RESTORATION PROCEDURES

Site Preparation

Site preparation is essential for any reclamation project, but especially at NPR-1. Site preparation includes ripping of compacted soils to a depth of 12-18 inches depending on the severity of the compaction, disking or harrowing to break up large soil aggregates, and where a straw/hay mulch is to be used for spreading of fertilizer. Soils on many of the sites that are being reclaimed are not suitable topsoils (USDA 1979) and therefore, soil nutrient levels are usually very low and approximately 80 lbs/acre of nitrogen and phosphorus are added to the soil.

Timing of site preparation is not as critical as are other phases of habitat restoration. The major concern is the preparation of the site under relatively dry soil conditions. Working soils when wet usually results in large soil clods requiring additional site preparation.

Reseeding

Early reclamation work on NPR-1 used hydroseeding and hydromulching techniques for the application of seed (O'Farrell and Mitchell 1985, U.S. Dept. of Energy 1979) with marginal results. This is not entirely unexpected, since hydroseeding is more commonly used in more mesic environmental conditions. When seed is applied by hydroseeding, the seeds are placed on the soil surface and germination is initiated. If the soil is dry at the time of application or if dry conditions exist after application, the chance of successful seed germination and establishment are minimal. It is for this reason the hydroseeding is only done on sites where drill seeding equipment cannot access and it is completed late in the season (November or December) in an attempt to decrease the time between hydroseeding and a precipitation event. Drill seeding has proven to be the most successful method for seed application.

Once a site is seeded, it is mulched at 1.5 to 2.0 tons of straw/acre. The straw is crimped into the soil with the use of a "sheep's foot" type crimper. The application of a straw or hay mulch improves soil moisture and adds needed organic matter to the soil (Kay 1978, USDA 1979, McGinnies 1987, NPI 1985, Oaks 1982 and Thornburg 1982).

Seed mixes and seeding rates used on NPR-1 have been evaluated since the early 1980s (O'Farrell and Mitchell 1985, Wolfe 1986a and 1986b, and Anderson 1987). Originally a wide range of species were used in reclamation work, because superiorly performing species were unknown. The use of native species was somewhat restricted since many, if not most, of the native species were not available in commercial quantities and at a reasonable cost. A native species of much interest is Pine bluegrass (*Poa scabrella*), but has not been available commercially. Winterfat, a species that occurs on NPR-1, has had limited success, due primarily to the unavailability of seed adapted to the more xeric conditions of Elk Hills. Red brome, which occurs abundantly on NPR-1 was originally included in seed mixes. It was completely eliminated from the seed mix in 1987 and 1988 with no apparent effect on its success, since the frequency of occurrence of red brome on revegetation sites is the same whether it was included in the seed mix or not. Natural sources of red brome seed abound on NPR-1 and since most disturbed sites that are revegetated are adjacent to these seed sources, seed of red brome invades a disturbed site within one to two years.

After four years of intensive reclamation work and monitoring, a list of preferred species are now included in seed mixes used for reclamation work on NPRC (Table 1). The rates of application of seed is 10-15 PLS (Pure Live Seed)/acre on drill seeded sites and double those amounts on hydroseeded areas (USDA 1979, Thornburg 1982, and Plummer et al. 1968).

Table 1. Plant species and seeding rates used for reclamation on NPR-1.

Species	**1985**	**1986**	**1987**	**1988**
Shrubs				
Atriplex lentiformis (Quailbush)	0	0	2.0	2.0
Atriplex polycarpa (Cattle spinach)	5.0	5.0	4.0	3.0
Eriogonum fasiculatum (California buckwheat)	0.5	0.5	1.0	2.5
Isomeris arborea (Bladderpod)	2.7	1.4	4.0	3.0
Ceratoides lanata (Winterfat)	5.8	5.8	5.0	2.5
Grasses				
Bromus mollis (Blando brome)	3.7	2.0	3.0	1.0
Bromus rubens (Red brome)	3.5	3.5	0	0
Festuca megalura (Zorro fescue)	0.4	0.4	0.8	0.7
Oryzopsis hymenoides (Indian ricegrass)	9.0	1.0	3.0	0.0
Schismus barbatus (Mediterranean grass)	1.3	1.3	0.1	0.2
Forbs				
Eschscholtzia caespitosa (Poppy)	0.1	0.1	0.0	0.1
Lasthenia chrysostoma (Goldfields)	T	T	0.0	0.1
Lupinus densiflorum (Lupine)	0	O	0.0	0.5
Lupinus nanus (Lupine)	0.3	5.0	0.0	0.5
Orthocarpus purpurascens (Owl's clover)	0	T	0.0	0.1
Phacelia tanacetifolia (Tansy phacelia)	T	T	0.0	0.2
Total PLS/lbs/acre	23.8	26.0	22.9	16.4

Timing for seeding of disturbed sites is critical and is completed in the fall, just prior to fall and winter precipitation (NPI 1985, Plummer et al. 1968). Under the sporadic precipitation conditions so frequent in the southern San Joaquin valley, fall seeding affords the seeds the greatest potential for germination and establishment.

Reclamation in xeric conditions such as those found on Elk Hills is often considered an impossibility with limited success. However, reclamation attempts have been successful when appropriate techniques are employed to maximize the effect of the small amounts of precipitation that are received. Reclamation efforts on NPR-1 are considered successful and contradictory to earlier perceptions, have been successful without supplemental watering.

MONITORING HABITAT RESTORATION SUCCESS

Monitoring reclamation work on NPR-1 began in 1987 in an attempt to document that over time vegetation on reclaimed sites was comparable to that on adjacent undisturbed sites. During the first and second growing season after a site is revegetated, a qualitative evaluation of reclamation success is made by visually estimating vegetative cover, litter, bareground, shrub, forb and grass cover, and by recording the species present (Table 2). The use of the site by wildlife is also noted by direct observation or by signs of use such as presence of burrows or scat. Erosion on the site is classified into one of five categories and a photograph of the site is taken for year to year comparisons. It is during the first years that shrubs become or do not become established and problems become evident (Ostler and

Table 2. Summary of qualitative data taken for sites reclaimed in 1985, 1986, 1987 and 1988.

Year Revegetated	Growing Season After Reclamation	% Cover	% Shrub	% Grass	% Forb	Annual Precipitation
1985	1		- Data not taken -			6.12
	2	21	- Data not taken -			2.03
1986	1	16	- Data not taken -			6.12
	2	26	12	75	13	2.03
1987	1	19	25	61	14	2.03
	2	31	36	47	17	1.77
1988	1	7	38	38	24	1.77

and Allred 1987, USDA Forest Service 1979). Any problems observed such as soil deficiencies or toxicities, are noted and corrective measures taken. Approximately 600 sites are evaluated annually.

In the fifth year after revegetation, the sites are evaluated to determine vegetative cover by species and species diversity by lifeform. This information is used to document quantitatively, the similarity of the revegetated disturbed site to adjacent undisturbed sites. A visual estimate of cover is made to the nearest percent for each plant species. Cover estimates are also made for rock, bare soil and litter. Density of grasses and forbs is estimated for a predetermined quarter of the meter square quadrat and shrub density is an absolute number of woody plants rooted in the meter square plot. Data is compared to control (undisturbed) sites located throughout NPR-1.

DATA SUMMARY

The information from the monitoring program has not only been useful to document reclamation success, but has also provided a means by which the reclamation technologies being used can be evaluated. For example, low species diversity and low shrub density were observed on sites revegetated in 1985 and 1986 (Table 3). To correct this, the amount of seed of the native or naturalized shrub species was increased and red brome, an aggressive naturalized annual that out-competes other desirable species, was deleted from the mix. Subsequent monitoring has shown an improvement in both the frequency of occurrence of shrub species and an increase in the contribution shrubs make to the overall vegetative cover.

It was observed that sites hydroseeded in 1985 and 1986 showed less total cover and especially shrub cover than sites drill seeded in 1987 and 1988. Another interesting discovery was that frequency of occurrence of red brome and filaree was the same for all years, even though neither species was included in the seed mixes used in 1987 and 1988.

In the fall of 1987, the revegetation of approximately 60 different cut and fill slopes was completed. Prior to this time, cut and fill slopes had not been considered for reclamation. A portion of the 60 sites were hydroseeded and hydromulched and the rest were hand broadcast seeded and mulched with straw and tacked with netting. Summary of the data collected one year after the sites were reclaimed show that hydroseeding in 1987 was successful for establishing saltbush, but greater cover and species diversity were experienced with hand broadcasting seed and straw mulching the sites (Table 4). It should also be noted that hydroseeding was completed a couple days prior to an intensive storm system

Table 3. Frequency of occurrence (%) of commonly seeded species on reclamation sites on NPR-1.

Species	Frequency of Occurrence (%) 1985	 1986	 1987	 1988[1]
Shrubs				
Atriplex polycarpa (Cattle spinach)	73	59	89	88
Eriogonum fasiculatum (California buckwheat	1	1	9	2
Isomeris arborea (Bladderpod)	7	16	37	34
Ceratoides lanata (Winterfat)	0	1	1	1
Grasses				
Bromus rubens (Red brome)[2]	97	89	91	92
Festuca megalura (Zorro fescue)	14	47	35	3
Forbs				
Erodium cicutarium (Filaree)[2]	89	80	67	42

[1] After one growing season.

[2] Not included in seed mix in 1987 and 1988.

Table 4. Comparison of two reclamation techniques used for side slope stabilization.

Reclamation Technique	- - - - - - - - - Cover (%) - - - - - - - - - Total	 Shrub	 Grass	 Forb	% Litter	% Bare-ground	# Shrubs Per Acre
Hydroseed/ Hydromulch	15.2	2.9	7.5	5.2	39.0	57.1	38,123
Broadcast/ Straw/Net	32.8	0.6	25.8	5.8	48.2	19.4	3,926

that dropped over two inches of rain on Elk Hills in a 3-5 day period. In other years hydroseeded sites may not have received moisture for several weeks, or in the case of 1988 and 1989, several months after seeding took place.

RECLAMATION COSTS

Costs associated with the reclamation of disturbed sites on NPR-1 include costs for site selection, materials and supplies, site preparation and seeding, and monitoring (Table 5). The cost for site selection ranges from $70 to $100/acre and includes costs for soil analyses, when necessary. Material and supply costs include those for seed (approximately 60% of total costs), straw (approximately 30% of total costs), and fertilizer (approximately 10% of total costs). Total material costs range from $200 to $750/acre. Higher material costs were experienced with hydroseeding and hydromulching in 1985 and 1986.

The costs/acre for procurement of a revegetation subcontractor to perform the reclamation work on NPR-1 has decreased over the past five years. This has been attributable to the concentration of reclamation work in a specific geographical region of NPR-1, a reduction in the number of seed mixes that are used, and a reduction in the amount of site preparation required, such as asphalt and concrete removal.

Monitoring of reclamation sites on NPR-1 began in 1987 when 300 sites were evaluated qualitatively. Approximately 490 sites were evaluated in 1988 and 586 in 1989. Costs/acre for monitoring have ranged from $68 to $88. When quantitative monitoring begins in 1990 for sites reclaimed in 1985, it is estimated that monitoring costs will be approximately $100/acre.

Table 5. Cost analysis for habitat restoration program from 1985 to 1989.

Year	# Sites/ # Acres	Site Selection $/Acre	Materials $/Acre	Labor $/Acre	Monitor $/Acre	Total $/Acre
1985	104/115	UNK	$754	$1,550	UNK	$2,301
1986	196/134	$82	$540	$1,708	$41	$2,367
1987	190/130	$107	$200	$1,523	$82	$1,987
1988	396/200	$68	$425	$1,615	$68	$2,237
1989	173/115	$75	$211	$728	$98	$1,495

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Planning, Rehabilitation, and Treatment of Disturbed Lands
Billings Symposium, 1990

ECORESTORATION MODEL FOR SURFACE MINED LANDS

P. Soni, H.B. Vasistha and Om Kumar[1]

ABSTRACT

Surface mining for minerals creates vast stretches of derelict lands which are, technically speaking, areas of "no value" from economic, social and aesthetic points of view. Problems due to surface mining are manifold, e.g. deforestation, soil erosion, pollution of water, air, noise, etc..., and depletion of nutrients.

This paper discusses the ecorestoration model developed by the authors for restoring surface mined lands in one of the most fragile ecological regions of the country. Use of ecologically suitable native species of grasses, shrubs, and trees for restoration leads to stabilization of overburden dumps in a short span of five to six years. At the same time, the model stimulates ecological succession of flora and fauna, helps water pollution control and is capable of generating socioeconomic return in terms of fuel, fodder, fibre, etc.

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INTRODUCTION

Surface mining is a devastating land use which not only destroys the original land use, but also introduces a number of ecological hazards. Surface mining causes loss of vegetation cover, soil erosion, pollution of water bodies and the atmosphere, depletion of nutrients and damage to social systems (Figure 1). Now the question arises, why should we disturb the landscape by mining knowing well enough that switching from the existing land use pattern to that of mineral extraction is going to cause immense harm to the ecological parameters of the site and to the cultural environment. However, we need minerals for our various daily requirements, industries, etc... and mining is accepted by society as a means of attaining these needs.

The area of land currently disturbed by mining in the world is estimated to be approximately 386,000 hectares per year and this figure is going to increase threefold by the year 2000. According to these figures, in the last quarter century alone, land degraded by mining would amount to nearly 24 million hectares, or in other words, 0.2% of the earth's surface. The mining industry in India is also a major sector of development; it is spread over an area of 700,000 hectares.

The most vital question before experts today is how humans can maintain balanced ecosystems and healthy environments, and at the same time, extract the minerals that are required to meet day-to-day human requirements. This is where the role of ecorestoration of mined areas comes into the picture. The ecorestoration model is applied to disturbed lands so that mining and the ecosystem may co-exist.

RESTORATION TECHNOLOGY

Restoration technology may vary from one mine to another. Variation will be introduced by different types of mines, geology and terrain, mineral excavated, overburden characteristics, pre-mining land use, and the ecoclimatic zone in which the mine is found. Therefore, before selecting an effective ecorestoration model, the following criteria should be taken into consideration.

1. Ecoclimatic zone to which the site belongs. This helps in selection of species suitable for restoring the sites with ecologically compatible species.

2. Determination of land use to which the area is most suited: agriculture, forestry, landscaping for recreational uses, fisheries, pastures, etc... (Table 1).

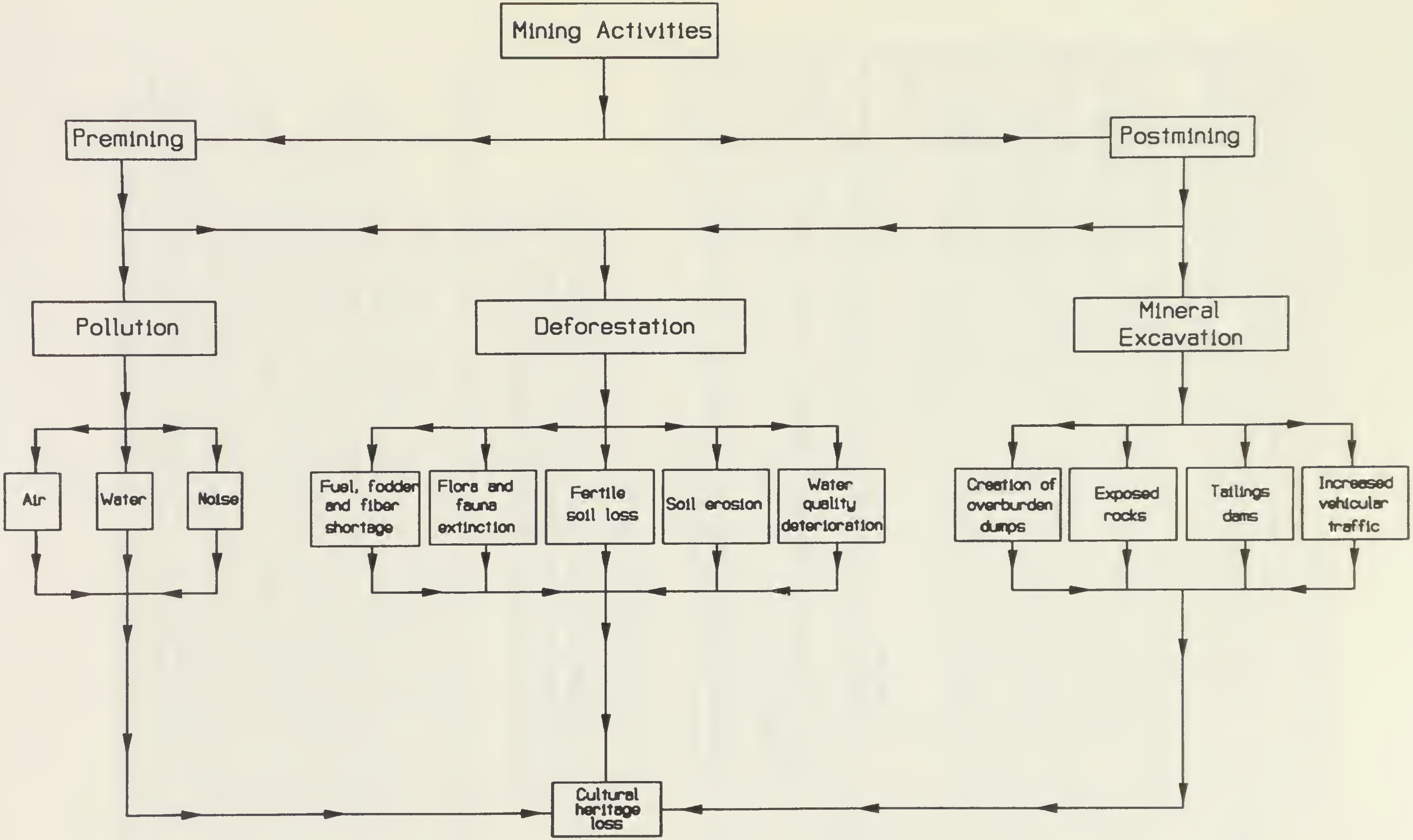

Figure 1. Example of pre- and postmining impacts.

Table 1. Land use determination.

Class	Symbol	Utility Group	Example
1	Ag	Good for agriculture	Topsoil intact, overburden undisturbed
2	Ls	Good for landscaping and recreational use	Mines close to habitations or towns; areas with exposed rock and soils in rock, etc.
3	F	Good for forestry and pasture	Partially disturbed or undisturbed overburden coarse texture
4	UF	Unfit for any productive use	Very coarse overburden consisting of rocks and boulders etc.; toxic to plant growth
5	V	Fisheries	Pit area covered with water

3. Mode of mining: whether by surface excavation or underground.

4. Characteristics of overburden: constituent horizons, rock fragments, mode of dumping, etc.

5. Spoil characteristics: pH (alkaline or acid).

6. Assessment of the problems created by mining. The problems may be deforestation, pollution of atmosphere or water, soil erosion or problems of any other kind.

Planning and development of the ecorestoration scheme should evolve within the confines of these criteria or problem areas.

Techniques for establishing vegetation on mined lands have been extensively studied (Hutnik and Davis 1969; Goodman 1974; Thomas 1977; Bradshaw and Chadwick 1986), however, there are only a limited number of quantitative reports dealing with the natural processes of plant community development (Brenner 1985; Vogel 1980; Soni et al. 1989). In India, due to lack of stringent environmental regulation until very recently, most of the mined areas remain in an environmentally disturbed state (Soni et al. 1989; Banerjee 1989). Recently, reclamation of disturbed lands has been undertaken in some of the mining areas of this country (Chaturvedi 1983; Sharma 1985; Soni and Vasistha 1985). However, most of these were attempts at tree planting utilizing the polybag planting technique. An exception was our ecological native species of shrubs, herbs, grasses, and trees to restore surface mined lands (Soni and Vasistha 1985). The ecorestoration model developed by the authors (Figure 2) is the basis for their reclamation projects on mined areas of Doon Valley and the Mussoorie Hills. It is described, in detail, in this paper.

Restoration and regrading of land is different from ecological restoration. The latter leads to ecologically stable systems capable of providing returns from both the abiotic as well as the biotic systems on a sustainable basis. Whereas, simply regrading and revegetating may or may not contribute to ecologically stable systems. Ecological restoration of areas mined for rock phosphate has been undertaken by the authors since 1982 with the collaboration of Pyrites, Phosphates and Chemicals Limited (a Government of India undertaking). Similar ecological restoration has been carried out by these scientists with the collaboration of Eco-Task Force 127 Inf. Bat. on areas mined for limestone. Both areas were surface mined.

At the rock phosphate mines, ore:overburden ratios were 1:3. At the limestone quarry, no overburden was removed except the shallow topsoil layer. Both of these areas are in the ecologically fragile, hilly region of this country and soil and water pose severe erosion problems. Loose overburden and lime result in sliding and erosion. Air and noise pollution are not critical problems at these sites, however. Prior to undertaking ecological restoration of these lands, the following aspects were taken into consideration.

1. Reconnaissance survey of adjoining unmined areas. Premining benchmark surveys could not be carried out in the mined areas (Soni and Vasistha 1986). Therefore, to have an idea of the original vegetation structure of the sites, reconnaissance of different components of flora in adjoining unmined areas was carried out.

2. Selection of species. On the basis of floristic surveys, as noted above, fast growing colonizing species were selected for trials on the mined area. While colonizing capacity and conservation value were the important criteria for selecting plant species, the socioeconomic requirements of the local residents were also given attention. Such factors as sustained fuel, fibre, fodder, food, etc... production, as well as suitable habitat (Table 2) were considered in plant species selection. In this way, while plant species use was based primarily upon ecological stabilization of the area, the needs of local people and wildlife returns from the site were weighed. In a similar manner, stabilization of water courses relied upon selection of

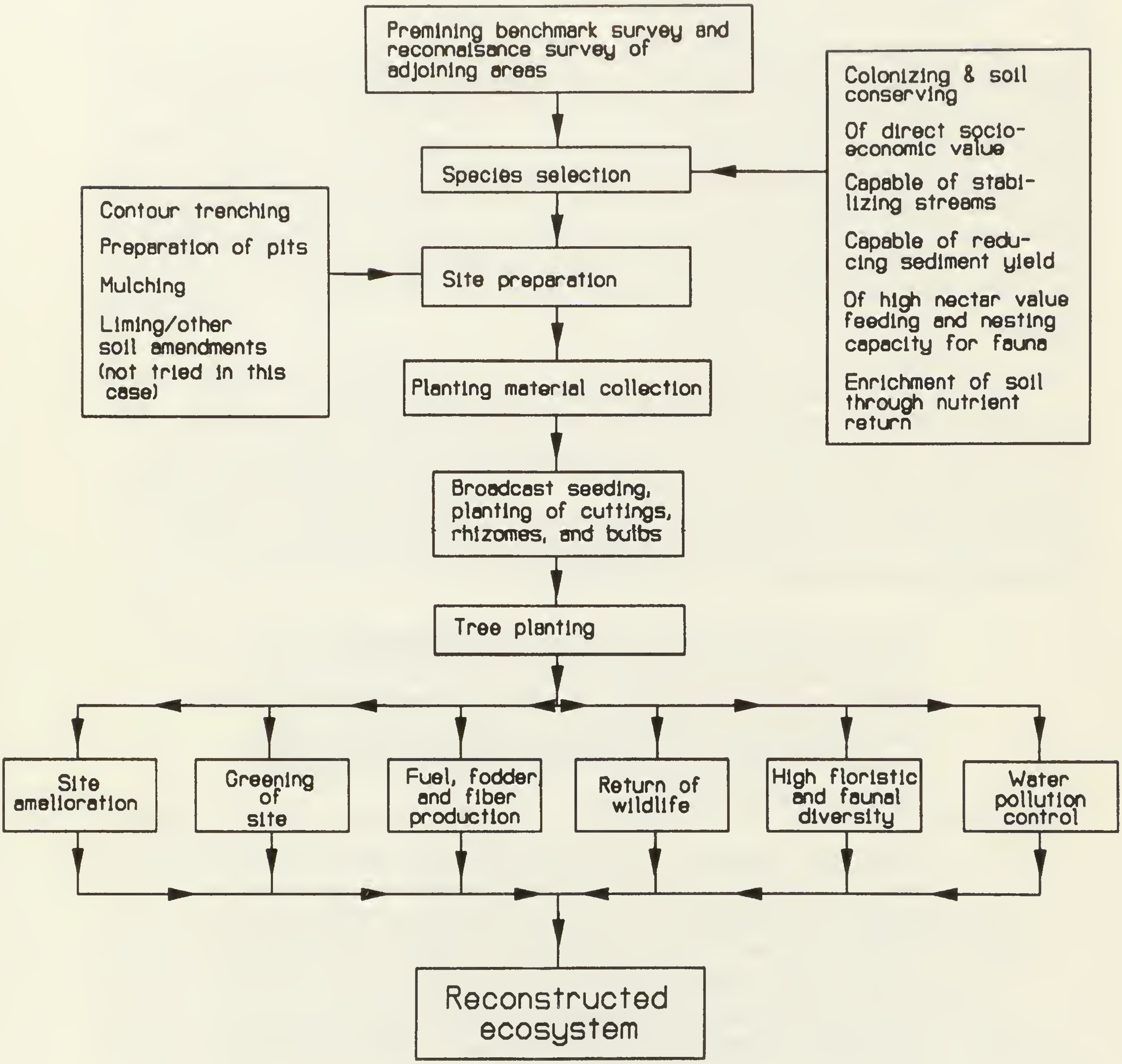
Premining benchmark survey and reconnaisance survey of adjoining areas
Colonizing & soil conserving
Of direct socio-economic value
Capable of stabilizing streams
Capable of reducing sediment yield
Of high nectar value feeding and nesting capacity for fauna
Enrichment of soil through nutrient return
Species selection
Contour trenching
Preparation of pits
Mulching
Liming/other soil amendments (not tried in this case)
Site preparation
Planting material collection
Broadcast seeding, planting of cuttings, rhizomes, and bulbs
Tree planting
Site amelioration
Greening of site
Fuel, fodder and fiber production
Return of wildlife
High floristic and faunal diversity
Water pollution control
Reconstructed ecosystem

Figure 2. Ecorestoration model for surface-mined lands.

Table 2. Species suitable for surface mine reclamation of areas mined for rock phosphate and limestone.

Plant Group	Plant Species	Mode of Propagation	Economic Utility
Trees	* *Acacia catechu*	Ds, Sl, Sp	Fo, Fu, Ti, Fer
	** *Dalbergia sissoo*	Ds, Sl, Sp, Rs	Fo, Fu, Ti, Fer
	* *Leucaena leucocephala*	Ds, Sl	Fo, Fu, Fer
	* *Salix tetrasperma*	Cu, Sl	Fo, Fi, Ss
	* *Trema politoria*	Sl	Fo, Fu, Fer
	*** *Wendlandia exserta*	Sl	Fo, Fu
	* *Cedrus deodara*	Sl	Ti
	* *Populus deltoides*	Sl, Cu	Pap
	* *Pinus roxburghii*	Sl	Ti
	* *Robinia pseudoacacia*	Sl, Rs	Fo, Fu, Ti, Fer
	** *Cupressus* spp.	Sl	Ti
Shrubs	*** *Buddleja asistica*	Ds, Sl	Med
	*** *Mimosa himalayana*	Ds	Fu, Fer
	*** *Rumex hastatus*	Ds	--
	*** *Vitex negundo*	Cu	Med
	* *Crotolaria sericea*	Ds	Fer
	* *Coriaria nepalensis*	Ds, Cu	Fo
	* *Ipomoea carnea*	Cu	--
	** *Dodonea viscosa*	Ds, Sl	--
	*** *Agave sislana*	Su, Bb	Fi
	*** *Debregeasia* spp.	Cu, Sl	Fo, Fu, Ss
Grasses and Sedges	*** *Pennisetum purpureum*	Rs, Cu	Fo
	*** *Arundo donax*	Rs, Cu	Th
	*** *Eriophorum comosum*	Ds, Tu	--
	*** *Saccharum spontaneum*	Rs	--
	** *Phragmites* spp.	Ds, Rs	Mat

* Species suitable for revegetation of rock phosphate mined area.

** Species suitable for revegetation of limestone mined area.

*** Species suitable for revegetation of both limestone and rock phosphate mined area.

Propogation = Ds-Direct seeding; Sl-Seedling; Sp-Stump planting; Cu-Cutting; Rs-Root stock; Tu-Tussock; Su-Sucker; Bb-Bulbils.

Utility = Fo-Fodder; Fu-Fuel; Ti-Timber; Fer-Fertilizer; Fi-Fibre; Ss-Streambank stabilization; Pap-Paper making; Med-Medicine; Th-Thatching; Mat-Matting.

species which can grow in and along water courses and reduce sediment yield. Consideration was also given to socio-economic conditions of the residents of the disturbed areas.

3. Collection of planting material. Based upon published literature or experimental trials, appropriate species were selected. Seeds, cuttings, bulbils, rhizomes or young plants of these grasses, sedges, forbs, and shrubs were collected from the adjoining area. Seeds were broadcasted and plant parts transplanted over the mined areas (Table 2).

4. Site preparation and planting. Preparation of the site prior to planting is important. For example, contour trenching was carried out on the 30° to 40° rock phosphate overburden slopes to break the continuity of the slopes. During the first and second growing seasons, emphasis is placed upon understory species (grasses, forbs and shrubs). During and after the third growing season, tree planting is undertaken. This sequence has been followed to favor slope stabilization and enrichment of overburden with organic material. In plains areas with no or moderate slope, however, tree planting can be carried out in the initial phases with seeding and transplanting of the understory species.

This model has applicability to other mine areas with modifications to meet the ecological, social and other factors of the concerned area.

Six to seven years after implementation of this program in rock phosphate mined areas, the ecosystem revealed the following features.

1. A stable ecosystem rich in floristic and faunistic diversity had developed (Soni et al. 1989a and 1989b).

2. Mine water sediment concentrations had been reduced by almost 50% after passing through stands of vegetation.

3. A diverse variety of soil fauna, about 28 species of birds and other vertebrates and invertebrates have invaded the areas (Bhatt 1989).

4. About 15 tonnes of leaf fodder and 10 tonnes fuel per hectare are harvested each year. In addition, 0.024 tonnes per hectare of fertilizers (nitrogen, phosphorus, potassium, calcium and magnesium) are returned to the soil annually (Figure 3).

The features of the limestone mined ecosystem cannot be defined at this time. Only two years of reclaimed ecosystem development have taken place on these sites. However, on the basis of results to date, it is presumed that within four to five years the area will not only be green and ecostable, but will also be capable of supporting species of a diverse variety.

The ecological monitoring of reclaimed rock phosphate mines six years after mining have shown the following results.

1. Percentage survival of native plant species on mined sites and overburden dumps is significantly higher (60%) as compared to the survival of exotic *Pinus* spp. (15%) (Soni et al. 1989).

2. The diversity of plants has increased significantly from the initial seeding and natural succession has been initiated.

3. Vegetation development has lead to production of leaf litter and has started nutrient cycling (Table 3). It is well known that litter decomposition is of great significance in site enrichment and amelioration of mined sites (Brenner et al. 1984).

4. As floral density has increased faunal density has also increased. These findings suggest that areas planted with vegetation producing large amounts of decomposable litter support large numbers of faunal species.

On the basis of these findings, it is concluded that if restoration of degraded lands is carried out on sound ecological principles, the area can be turned green in a span of only five to six years. Such rates can fulfill the objectives of land resources conservation highlighted in the world conservation strategy (1980) viz; maintain essential ecological processes and life-support systems, preserve genetic diversity and sustainable utilization of species and ecosystems.

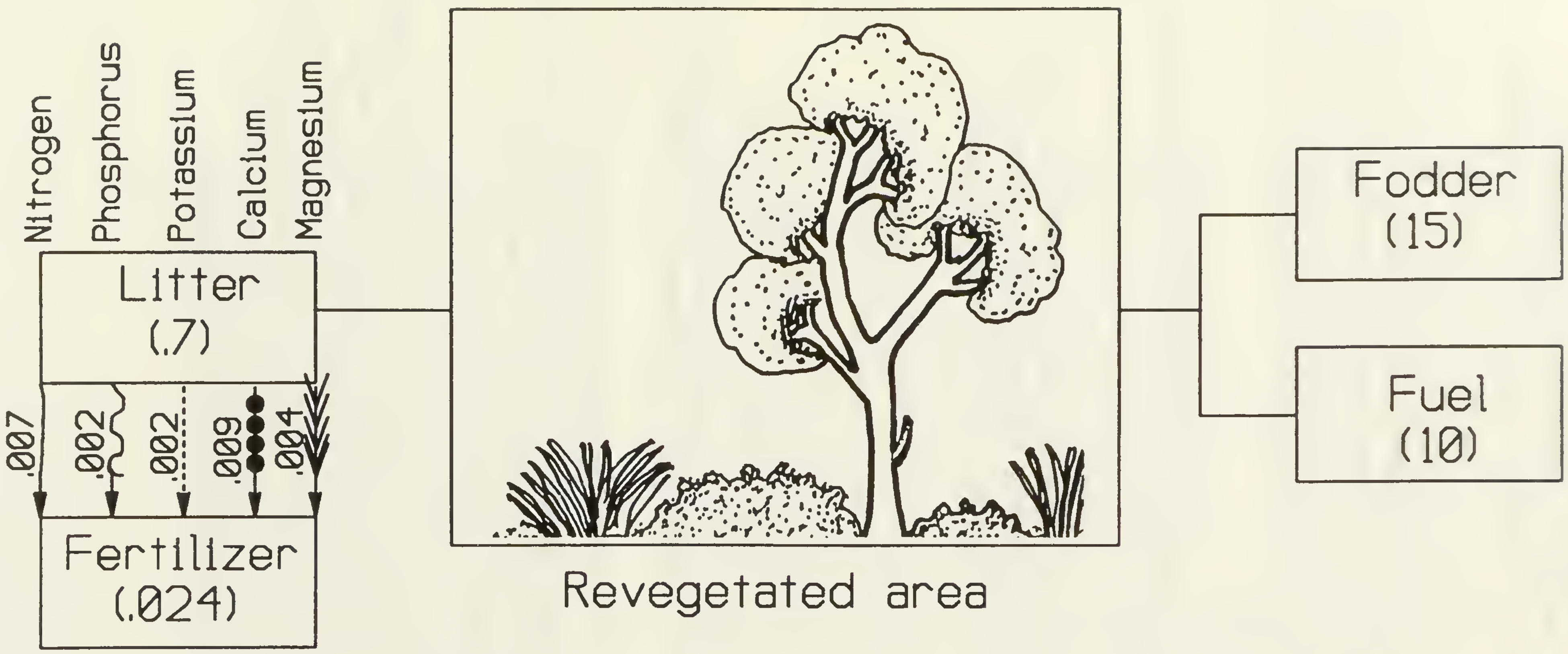

Figure 3. Benefits derived from 6-year-old revegetated mined land (tons/hectare).

Table 3. Results of ecological monitoring after six years of reclamation.

Ecological Factors	Quantity
No. plant species	26
Vegetation density/ha	266,393
Soil fauna density/ha	11,332
Litter production tonnes/ha	776
Nutrients (tonnes/ha)	
Nitrogen	0.007
Phosphorus	0.002
Potassium	0.002
Calcium	0.009
Magnesium	0.004
	0.024

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Planning, Rehabilitation, and Treatment of Disturbed Lands
Billings Symposium, 1990

RECLAMATION PLANNING AND OPERATION AT THE MAE MOH LIGNITE MINE, THAILAND

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ABSTRACT

The Mae Moh Mine is a large open cut lignite mine situated in Northern Thailand. The mine produces lignite for coal fired power stations located adjacent to the mine. Current mine production is approximately 9 Mtpa providing lignite to eight power stations with a total output of 1,125 MW. The power development plan for Mae Moh provides for 19 power stations by the year 1999 which will require lignite production to be increased to 30.5 Mtpa and overburden will be mined at a rate approaching 300 Mtpa.

Environmental management and reclamation planning at Mae Moh are major issues due to water quality impact and land use conflicts. This paper presents the key elements of the reclamation master plan and works strategy for progressive reclamation and water pollution control.

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INTRODUCTION

The Mae Moh Mine is an open cut lignite operation situated in northern Thailand, 630 km north of Bangkok (by road). The closest major center is the city of Lampang which is 28 km west of the mine (see Figure 1).

The mine is located within the Mae Moh Valley which is 18 km long and 9 km wide (see Figure 2), with the coal deposit itself 8 km long and 4 km wide.

There are many traditional farming villages within the Mae Moh Valley. Several of these have been relocated to make way for mining operations. Others are planned to be resettled or are in the process of being resettled to facilitate future mine expansion.

Teak reafforestation areas impinge on land required for mine and power station development. The Nam Mae Moh River at its' tributaries flow through the valley and across the mining area.

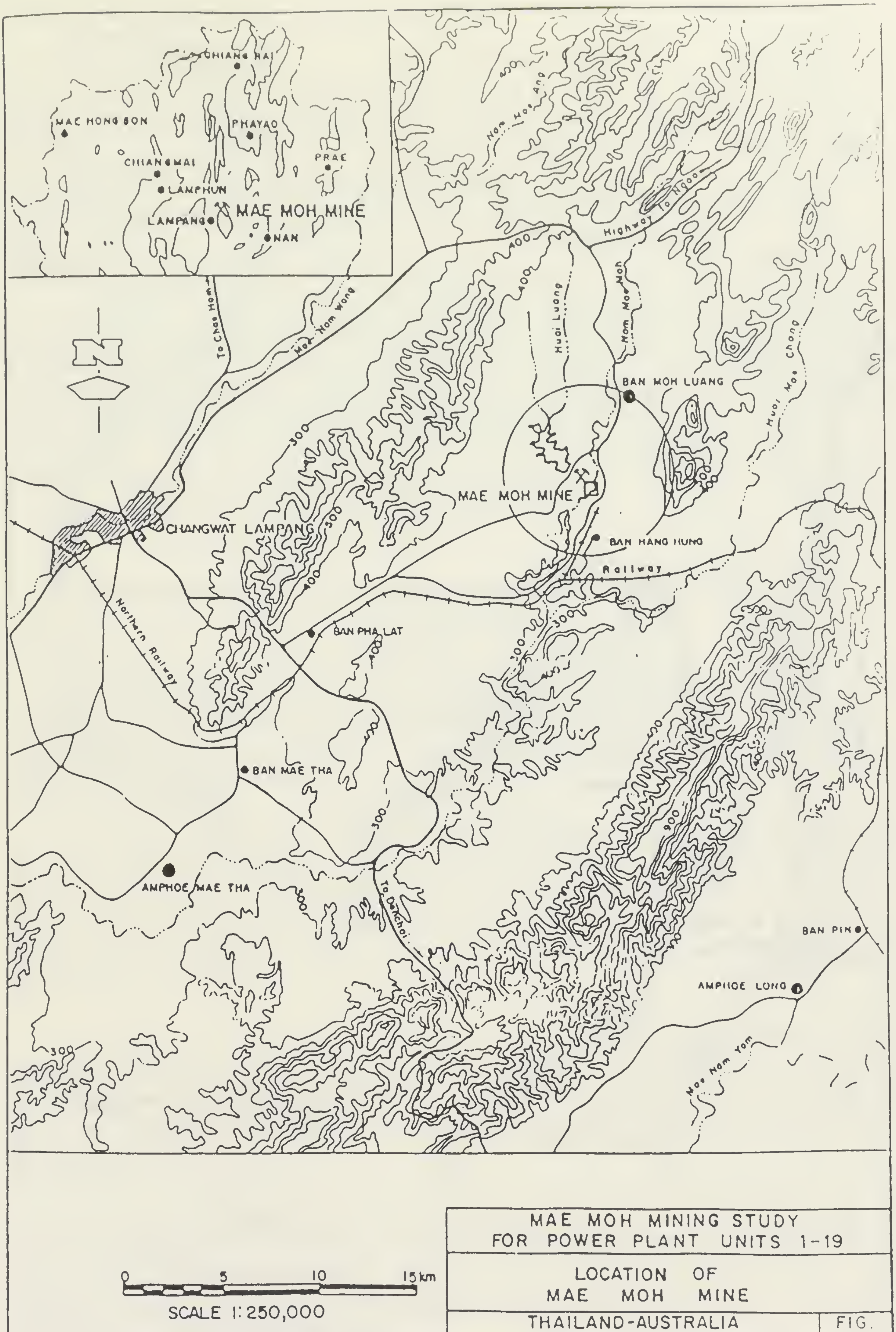
The Mae Moh coal deposit was discovered more than sixty years ago by villagers who noticed spontaneous combustion of coal along the deposit outcrops.

Between 1917 and 1932 the Royal State Railway Department, led by its Commissioner, General H.R.H. Prince Kampaeng Petch Agkrayotin, encouraged prospecting for coal throughout Thailand. By 1927, King Rama VII realised that coal would be an important source of energy for Thailand and decided to conserve the coal deposits of the country for government purposes. This included the Mae Moh deposit.

In 1951 the Royal Thai Department of Mines, later called the Department of Mineral Resources (DMR), began systematic investigation of the coal deposit at Mae Moh.

The Electricity Generating Authority of Thailand (EGAT) constructed a 75 MW power station (Unit 1) at Mae Moh in 1976-77. Coal production was then 0.4 Mtpa. This was followed in 1978-79 by power station Units 2 and 3 (75 MW each), requiring coal production to be expanded to 1.5 Mtpa. Units 1, 2 and 3 are located to the west of the existing pit.

In the period 1983 to 1986, EGAT constructed power station Units 4, 5, 6 and 7, each with a capacity of 150 MW. These are located east of the eastern deposit subcrop. As part of the power station expansion to Unit 19, power station Units 8 to 11, each of 300 MW capacity, are being erected adjacent to Units 4 to 7. Unit 8 is now fully operational and Unit 9 will be commissioned late in 1990.

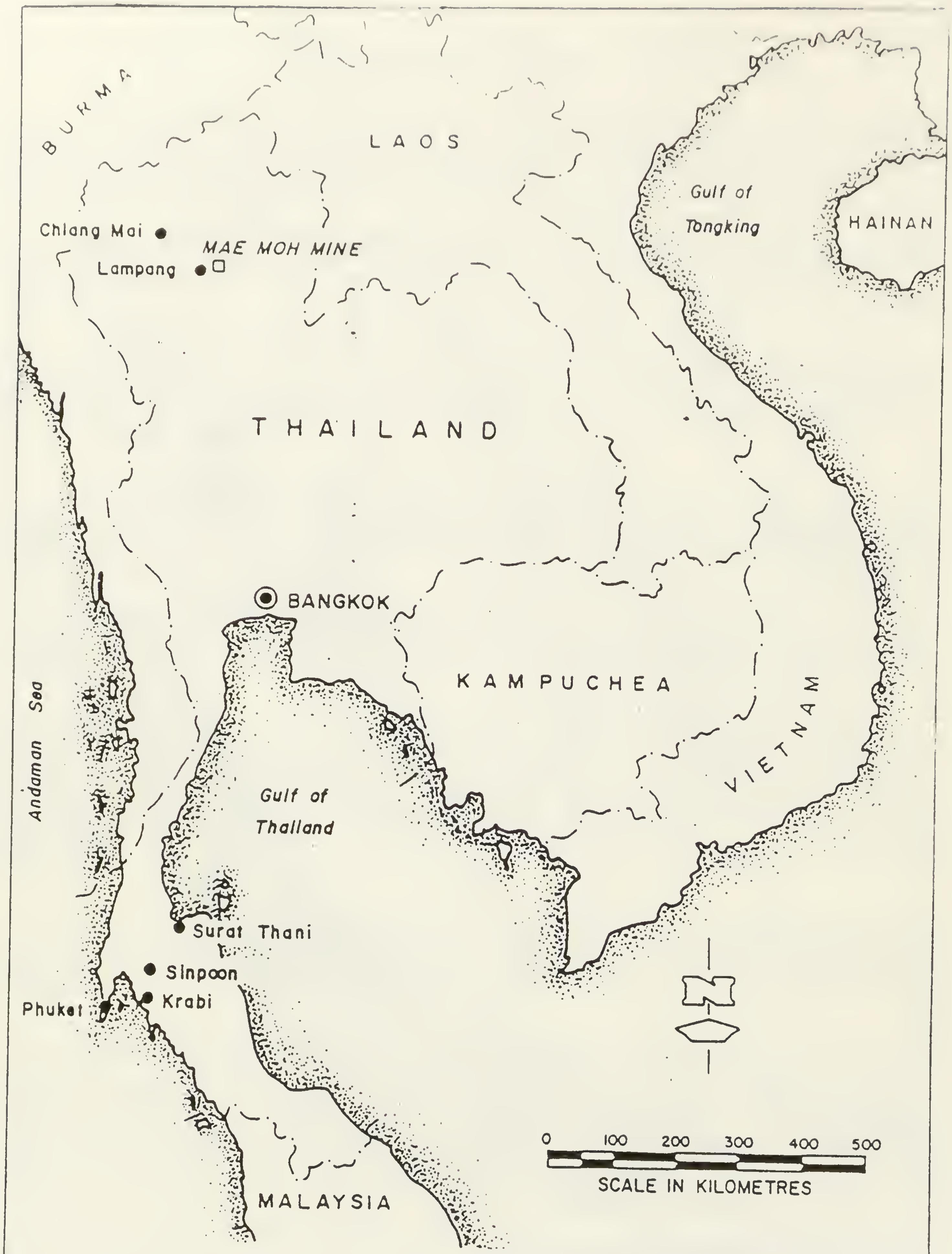


MAE MOH MINING STUDY
FOR POWER PLANT UNITS 1-19

LOCATION OF
MAE MOH MINE

THAILAND-AUSTRALIA
LIGNITE MINES DEV. PROJECT

FIG.
2



MAE MOH
RECLAMATION PLAN

LOCATION PLAN

THAILAND-AUSTRALIA
LIGNITE MINES DEV. PROJECT

FIG.
1

EGAT's current Power Development Plan provides for up to 19 power station units all in close proximity to the Mae Moh Mine. Completion of these units by 1999 will require lignite production to increase to approximately 30 Mtpa and overburden removal to increase to approximately 300 Mtpa. This will result in mining being carried out at depths exceeding 400 metres in some areas of the mine. The Mae Moh Mine will then be the biggest shovel/truck mine in the world.

Assistance is being provided to EGAT through the Thailand-Australia Lignite Mines Development Project (TALMDP), which is an Australian International Development Assistance Bureau project commissioned to Australian mining consultants Coleman and Associates Pty Ltd. The project commenced in October 1983 with the objective of providing assistance to the EGAT in the development of lignite mines in northern and southern Thailand. The assistance includes environmental management and reclamation aspects associated with the mining operation. These aspects are presented in this paper.

PREPARATION OF A RECLAMATION MASTER PLAN FOR MAE MOH

Reclamation works have been carried out at the Mae Moh Mine for a number of years. The revegetation program has been highly effective although some failures were experienced as a result of the presence of toxic overburden (this aspect is discussed later).

To direct reclamation works, it was necessary to firstly prepare a reclamation master plan which would address the situation when all economical coal has been extracted from Mae Moh and reclamation works are complete. The Reclamation Master Plan presents the final landform and final land use. Under the current project plan, this situation will be achieved about the middle of next century.

End-use planning criteria were adopted incorporating reclamation guidelines agreed between TALMDP advisers and the Reclamation Sections of EGAT's Mine Engineering and Mine Operation Departments, augmented by criteria from the Royal Forestry Department. The land use categories, proposed location and criteria are listed in Table 1.

At the completion of the current project plan, large outside dumps will have been completed west, north and northeast of the mining area about 150 m above the natural ground surface. A large in-put dump will also have been created to a level about 50 to 60 m above natural ground surface in the mined out

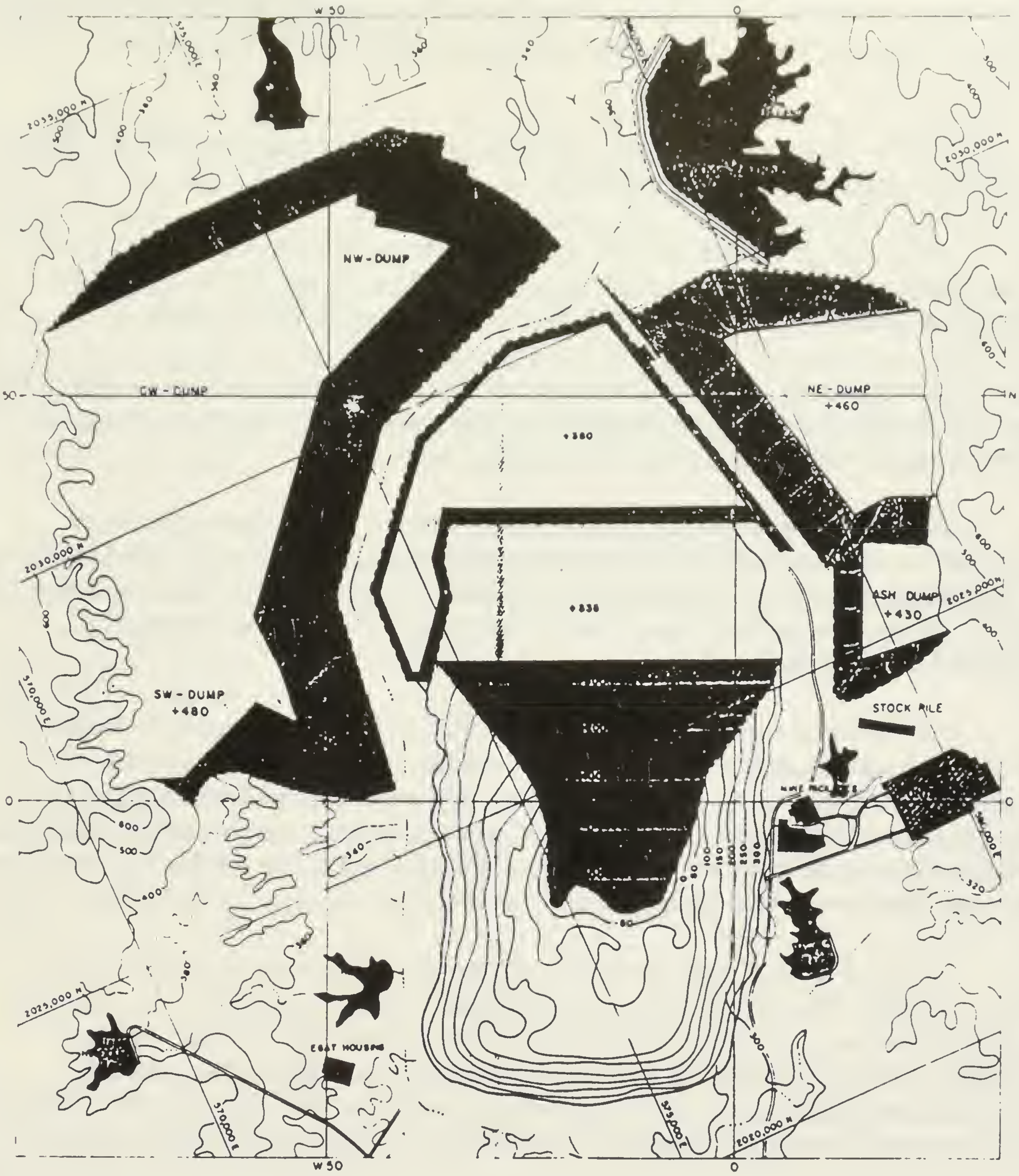
TABLE 1: POST MINING LAND-USES

Land-use Category	Proposed Location	Determining Criteria
Teak forest	Replace existing	Same area as existing.
Settlement	Dump surfaces	5,000 Rai of forest per settlement. 150 Rai of forest per family.
Housing/agriculture	Dump surfaces	15 Rai of land per family.
Forest	Dump slopes Additional areas as available.	Areas not suitable for other end-uses.
Water storages and drains	Where necessary	To suit end-uses.
Roads	Where necessary	To suit end-uses.
Recreation	As existing plus other locations to suit chosen facility	Golf course, viewing area, picnic area, water sports.
Potential industry	Existing	Existing infrastructure.

area of the pit. The final dimensions of the pit and dumps are shown on Figure 3. The total area impacted by dumps and mining will be approximately 80 sqkm.

A large void will be left around the southern margin of the pit. The void will be 400 m deep, 3,800 m east-west and 5,000 m north-south. When groundwater pumping is terminated at the end of the life of the mine, groundwater and rainfall/runoff will fill the void and overflow into Nam Mae Moh.

The western and northern dumps together will provide sufficient area for four villages including the prescribed areas of forest and agricultural land. The southern and northeastern slopes of the dump will be covered with screen planting comprising fast growing forest trees. Other slopes will be covered with teak forest, the area of which will be equal to that part of the teak forest to be overdumped. Most of the teak will be planted before overdumping takes place. By that time, the existing teak forest will have been harvested.



— — WASTE CONVEYOR ALIGNMENT

— COAL CONVEYOR ALIGNMENT

MAE MOH MINING STUDY
FOR TOTAL ECONOMIC RESERVE

DUMPING AREAS

THAILAND-AUSTRALIA
LIGNITE MINES DEV. PROJECT

FIG.
3

Runoff from the western mountains will flow onto the dump and through watercourses close to the villages. Overflow will pass down drop structures to the drains around the toe of the dump, through pondages and into the western diversion channel.

The northeastern dump will have enough area for only one village. This will be the first dump to be completed.

The in-pit dump will provide enough area for two villages. The southernmost village will be adjacent to the large lake. Close to the shore of the lake a significant area of shallow water will be left to encourage fish breeding.

Extensive recreational facilities are to be provided around the northern and eastern shores of the lake in the vicinity of the existing golf course, picnic area and viewing point. This may well include boating facilities.

The mine and power station facilities, and industrial areas should be adapted to other uses suitable to ongoing industrial development within the valley. The precise nature of this should be addressed in about twenty years from now (2010) when more will be known about the future industrial or commercial direction villagers wish to take.

All drainage and water storage structures will be maintained for future use. During the mining period, many of these will be used as settling and containment ponds to avoid spilling contaminated water into watercourses flowing from the mining area. Experience has shown that within two years of the completion of earthworks, runoff quality is good and can flow naturally into watercourses without causing adverse impacts downstream.

Seepage springs from the waste dumps are saline and are a major long term concern. This concern has been identified and investigations are currently being carried out to develop the most appropriate management and control strategy. In the long term, it is likely that the seepage will be directed into evaporation/holding basins for release during high flow (flood) conditions. Details of this controlled release strategy are the subject of the ongoing investigations.

RECLAMATION STRATEGY AND STAGE PLANS

A major concern at Mae Moh is the high level of soluble salts which are released from the overburden following mining and exposure. The overburden contains a relatively high content of sulfur (2 to 6%) occurring mainly as fine grained pyrite but also a very high content of calcium carbonate (average greater than 15% $CaCO_3$ but ranges from 0 to 60%). Seepage and drainage from dumping areas have a composition typical of neutralised acid mine drainage and approach saturation with gypsum. Therefore, water pollution control is a major objective of reclamation and environmental management at Mae Moh.

Reclamation provides for all mine slopes to be progressively revegetated to minimise pollution of runoff water. It has been established in field trials at Mae Moh that after two years of reclamation a soil profile can be developed which isolates runoff water from overburden and minimises the contamination of runoff.

Most of the cost associated with mine reclamation relates to the movement of large quantities of waste material. At Mae Moh, reclamation has been comprehensively incorporated into mine planning and operations. Waste will be dumped in the correct place and in the correct configuration in the first instance so that subsequent rehandling will not be required. When mining is completed in an area of the pit, the reclamation group will also provide for ongoing maintenance.

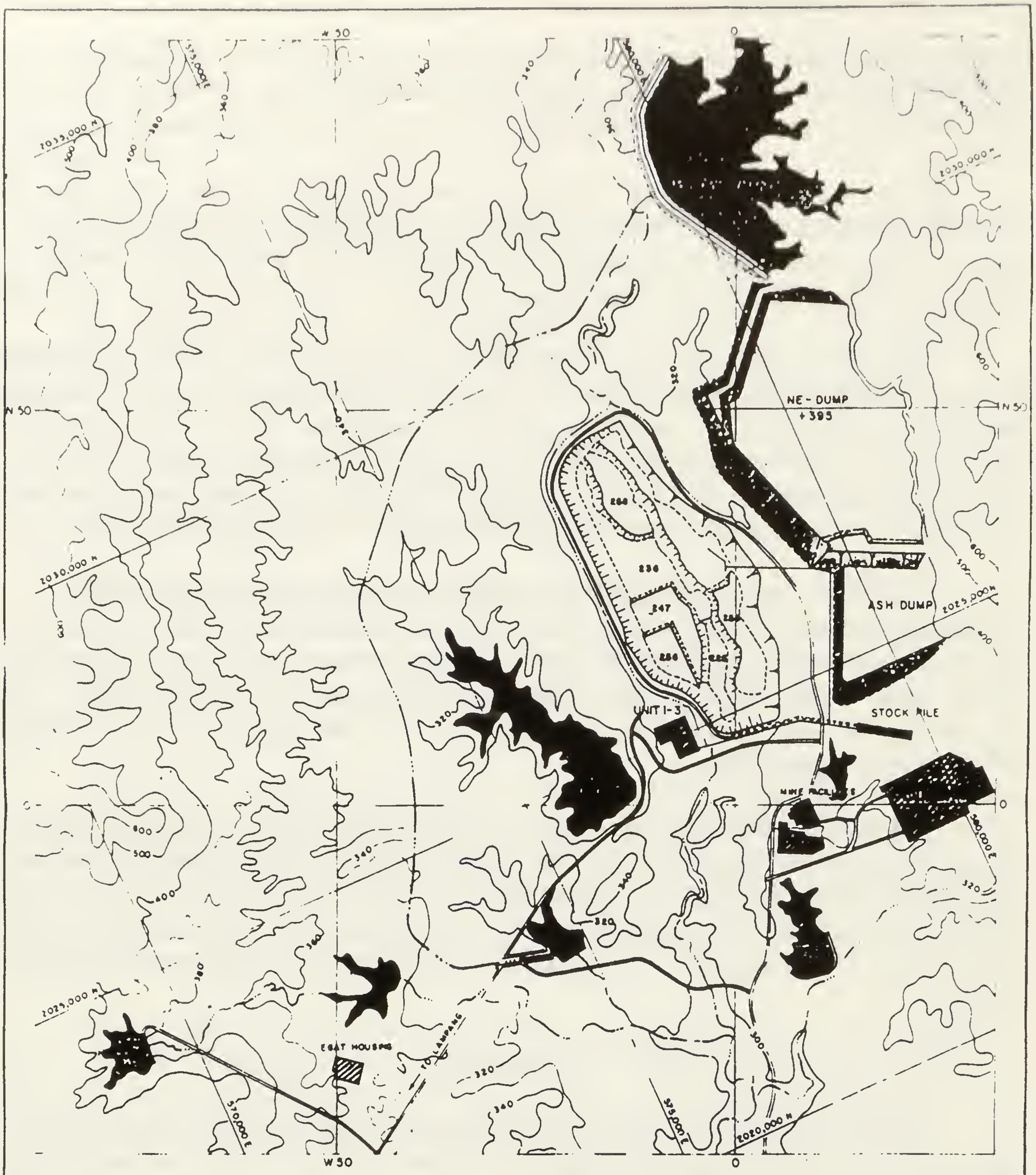
It has been agreed with EGAT senior mine management that all mine slopes and surfaces, which remain inactive for a period of two years or more, should be reclaimed. If the slope or surface will subsequently be overdumped or mined, then intermediate reclamation will be undertaken. If it is not to be overdumped or mined, then final reclamation will be undertaken in line with the Reclamation Master Plan.

The current extent of the mining and dumping operation at Mae Moh is shown on Figure 4. Figure 5 shows the projected extent of the operation at the year 2000. Figure 3, identified previously, shows the final extent of mining and dumping at the end of the current project plan at year 2023. The major element of the strategy for progressive reclamation of the Mae Moh Mine are discussed below.

Pit Slopes

Pit slopes exposed over the next ten years will be subject to intermediate reclamation. This has commenced on the lowwall. The lowwall is excavated to a buried sub-crop and so comprises benches and batters configured similarly to highwall slopes. Drainage has already been established on benches and drop structures have been constructed.

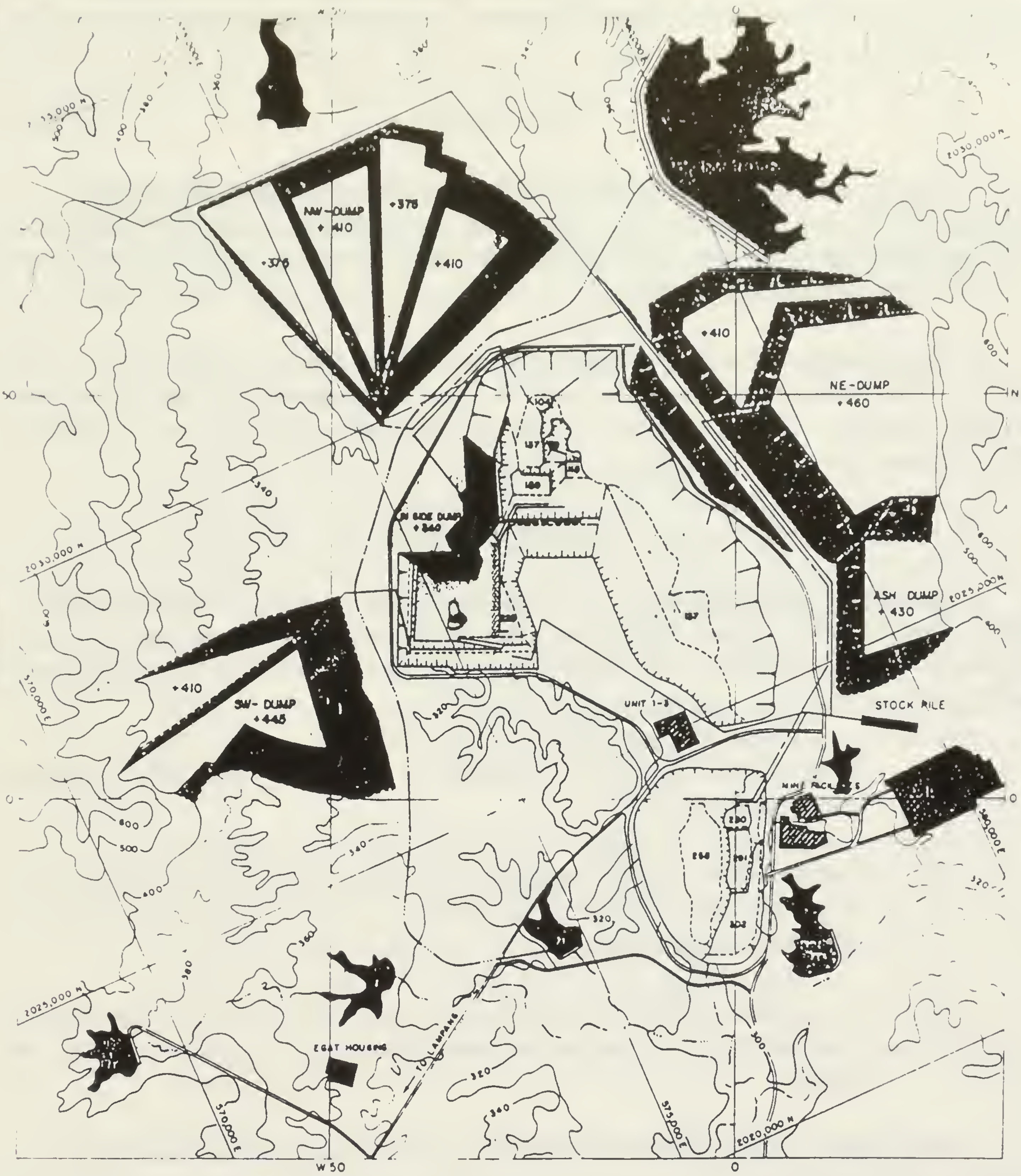
In most cases the lowwall will be the floor of the lower coal seam and dipping at 9° C to 22° C. If lowwall surface runoff is not intercepted, then massive scours will occur possibly leading to pit instability. To avoid this requires the construction of drains and drop structures.



- - - —WASTE CONVEYOR ALIGNMENT

-COAL CONVEYOR ALIGNMENT

MAE MOH MINING STUDY FOR POWER PLANT UNITS 1-19	
DEVELOPMENT STAGE PLAN YEAR 1990	
THAILAND-AUSTRALIA LIGNITE MINES DEV. PROJECT	FIG. 4



— · — WASTE CONVEYOR ALIGNMENT

— COAL CONVEYOR ALIGNMENT

MAE MOH MINING STUDY
FOR POWER PLANT UNITS 1-19

DEVELOPMENT STAGE PLAN YEAR 2000

THAILAND -AUSTRALIA
LIGNITE MINES DEV. PROJECT

FIG.
5

Excavated slopes require adequate drainage structures. This is also required for good operational management. Excavated batters will be dozed to 1:2 to facilitate revegetation.

Dump Slopes

Dumps will be placed by both trucks and conveyor/spreader systems. Dump stability has been addressed on a long term basis to ensure the safety of civil structures such as roads and suitably designed buildings which will be constructed long after mining passes.

Slope surfaces on dumps will be dozed to 1:3. Overall dump slopes will be 1:6:25. Final surfaces will be contoured to form catchment areas and to provide surface drainage. This must cope not only with direct rainfall but runoff from the slopes above the dump surface.

Waste Placement

A waste monitoring programme has been underway at Mae Moh since 1986. This has categorised waste into three categories according to toxicity and suitability for reclamation. The categories and management recommendations are as follows:

(i) Toxic (Type I) material. Should not be placed within five metres of any dump surface.

(ii) Undesirable (Type II) material. Should not be placed within two metres of any surface. It should also not be left exposed on any intermediate surfaces.

(iii) Acceptable (Type III) material. Should be selectively placed on outer surfaces of dumps to provide an overall cover of at least two metres.

Drill core testing is being carried out to provide advanced warning and location of toxic materials for consideration in the five year mining plans. Also, blast hole drill cuttings are being tested to help develop an inventory of waste types and to locate toxic material.

Revegetation

Current revegetative techniques for both ground cover and tree planting at Mae Moh Mine are generally proving to be successful. The majority of available areas have been reclaimed. EGAT's golf course and viewing areas have been given particular attention and have been completed to a high standard. These are both in old dumping areas. The southern wall of the NE dump has been sown with ground cover and planted with trees. The southern and western walls of the ash dam are revegetated. Preparation of lowwall slopes for revegetation has commenced.

Experience gained from reclamation research and from observations of tree planting field trials has demonstrated that most grey claystone (Type III material) is an effective plant growth medium. Waste dumps are therefore being revegetated planting directly into waste material using the following procedure:

- ripping - the surface to be planted is scarified by ripping along the line of contour;
- tree planting - a hole is dug to the appropriate diameter and depth to suit the rooting characteristics of the species being planted. A quantity of organic material, proven to ensure successful growth, is introduced into the hole. A seedling is planted into the organic material and securely staked. It is currently common practice to plant large blocks of the same species;
- ground cover - a mixture of grass and legume seed is broadcast over the area to provide a soil enriching ground cover and for erosion control;
- maintenance - ground cover is cut three to four times per year for the first four years. Cut material is carried away once each year;
- watering - tree seedlings are watered in the dry season, about 18 times over each of the first three years growth; and
- hoeing and fertilising - each tree is hoed and fertilised two to three times only.

Topsoil material is only used on areas to be landscaped requiring even, grassed surfaces. Three hundred millimeters of selected topsoil material is placed for this purpose.

Water Quality Control

Management of Contaminated Water

Water quality upstream of the mining operation at Mae Moh is characterised by low salinity, high hardness and is slightly alkaline. Mine water is characterised by high salinity, high hardness and contains moderate to high concentrations of sulphate, calcium and magnesium.

Water collected in mine sumps is contaminated by dissolved salts contained in:

- runoff from bare dump surfaces and exposed mine areas;
- dump seepage; and
- groundwater inflow to pit (particularly where inflow occurs within or near toxic Type I strata).

Although the mine water is unsuitable for human consumption, power station or agricultural irrigation, field tests indicate that prolonged use in watering reclamation areas does not lead to a measurable salt build-up in the soil. This is most likely due to formation of gypsum (Ca and SO_4 are the dominant dissolved salts) within the profile and the flushing that occurs during the wet season. This suggests that irrigation or land application may be an acceptable way to dispose of excess contaminated water.

However, discharge of the mine water and dump drainage into the Nam Mae Moh catchment is adversely affecting water quality. The average annual concentration of dissolved solids in the main reservoir downstream of the operation has more than doubled since the commencement of the monitoring program in 1979. The TDS level in the reservoir has increased from 300 mg/l in 1979 to 750 mg/l in 1988. Strategies and investigations are now in place to control the water pollution problem so that further unacceptable deterioration in water quality does not occur.

The first method of dealing with contaminated water of the type associated with mining at Mae Moh is to minimise the quantity which becomes contaminated. At Mae Moh, all fresh water entering the mining area from the north is intercepted and directed around the mining area and eventually into Nam Mae Moh. Cut-off drains will also be constructed around waste dumping areas to intercept fresh water inflows and carry them into the diversion channel.

The second method of dealing with contaminated water is containment. Water storages have been planned adjacent to each waste dump and within each pit to contain runoff and seepage. The quality of water in dumps will be monitored. The water will be used for mine purposes. Excess contaminated water will have to be pumped to reclamation sites and sprayed over large areas so that the water is lost by evaporation, transpiration and absorption. The use of contaminated water for dust suppression at waste conveyor transfer points is also being investigated.

Toxic Type I strata exposed in the pit will need to be covered to avoid contact with surface water. In-pit water management will be planned to avoid contact with these toxic strata.

The third method of dealing with contaminated water is to revegetate all surfaces and slopes soon after mining so that a soil profile is created. Within two years of planting, the contamination of runoff water will cease.

CONCLUSIONS

The massive expansion of the Mae Moh Lignite Mine over the next 10 years and on-going mining after this expansion at a rate approaching 300 Mtpa of overburden and waste is a major environmental concern. The major issues associated with the mining operation are the potential for unacceptable water pollution in the Nam Mae Moh catchment and the need for effective reclamation and long term land use on the reclaimed mined land.

The Electricity Generating Authority of Thailand (EGAT) are committed to sound environmental management and have recently established an environmental management coordinating group that includes all EGAT departments so that information and recommendations can be effectively communicated and actions carried out. The power development plan and mine plan for the expansion have been completed in great detail. The next decade will see major emphasis on environmental management and reclamation.

ACKNOWLEDGEMENTS

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Planning, Rehabilitation, and Treatment of Disturbed Lands
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DESIGN AND MANAGEMENT OF ENVIRONMENTALLY SOUND MINE WASTE DISPOSAL OPERATIONS IN WET ENVIRONMENTS WITH PARTICULAR EMPHASIS ON ACID MINE DRAINAGE AND CYANIDE

S.D. Miller, Ph.D.[1]

ABSTRACT

Development of mineral resources in the Asian/Pacific region are a particular concern due to the generation of solid waste and disposal of this waste in a wet and humid environment. This paper addresses the major geochemical issues associated with mine waste disposal under these conditions with particular emphasis on acid mine drainage and cyanide.

A strategy is presented for classifying the acid forming potential of mine waste based on the acid-base account and the net acid generation (NAG) confirmation test. The need for a correct and adequate sampling strategy is highlighted since sample selection is the most critical step.

The behaviour of cyanide in gold tailings is discussed and the results of a recent tailings dam investigation presented. These results confirm that significant attenuation or reduction in cyanide and associated complexed metals occur within the dam.

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INTRODUCTION

The development of mineral resources in the Asian/Pacific region are a significant environmental concern due to the generation of solid wastes and disposal of these in a wet, humid environment. The combination of mining wastes and a wet environment presents particular concerns with respect to contaminated leachate generation and chemical contamination of the immediate environment. Waste rock and process waste (tailings) are the two major solid wastes of concern. These waste materials generally require disposal on site and thus become major management considerations. In the short term their disposal impacts on the overall water management scheme, and ultimately they require reclamation prior to decommissioning to minimise long term impact.

The assessment and prediction of waste characteristics is paramount to the development of an environmentally sound waste management operation. In practice, waste handling operations can be designed and managed to ensure that any toxic or potentially toxic material is disposed of in a controlled manner. The resulting control of runoff and leachate quality assists in site water balance management and generally reduces the cost of waste water treatment and disposal.

A number of factors determine the significance of waste management issues at a particular site. These include the nature of the deposit, the mineralogy of the ore, the processing operation as well as the physical environment. Therefore, waste disposal and management must be considered on a site-specific basis.

This paper addresses the major geochemical factors in the development of environmentally sound waste management operations with particular attention to gold mining and processing. Many of the concepts and issues presented are applicable to all types of mining operations including base metal, mineral and coal.

WASTE GEOCHEMISTRY

The most common geochemical problem associated with waste disposal at mining operations is the potential for sulfide generated acidity and associated high levels of soluble trace and heavy metals. However, in tailings the chemicals added during processing are also important considerations. In gold mining and processing developments, the management of cyanide during the operation and the long term fate of cyanide in the tailings are major issues.

More specifically, the important geochemical characteristics that must be addressed are:

- acid forming potential of waste rock and tailings;
- content of heavy metals and specific ions;
- leaching characteristics and solubility of constituent elements under different environmental conditions;
- chemical composition of process water and tailings liquor; and
- the fate of cyanide in the tailings, in particular, the form and content of metallocyanide complexes.

To assess the geochemical characteristics of waste materials, it is necessary to determine basic chemical parameters such as the sulfur content, the capacity of the waste to neutralise acid, the solubility of constituents in the waste under natural pH conditions, and the total element composition. In addition to these basic parameters, it is frequently necessary to carry out applied leaching tests and specialised solubility and extraction procedures. In relation to cyanide tailings, it is also necessary to assess the forms and concentration of residual cyanide in the liquor as well as decay characteristics.

In addition to the geochemical characteristics, it is essential that the physical and hydrological characteristics of the waste materials are considered since the control options for minimising environmental contamination will be dependent on effective incorporation of the geochemical characteristics into practical engineering design. In other words, the engineering implications of the geochemical characteristics must be effectively communicated to the design and management personnel.

The purpose of characterising waste material and determining the geochemical behaviour is to identify potential environmental concerns and to provide criteria for the design and management of the waste disposal operation. As stated earlier, the potential for acid generation and the fate of cyanide in the tailings are the two major environmental contamination concerns at gold operations. These aspects are discussed in this paper.

Acid Forming Potential and Acid Mine Drainage

The most critical aspect of an investigation aimed at determining the acid forming potential of mine waste is sample selection. It is essential that individual profile samples are selected and include both waste rock and ore. Composite samples give biased results, generally underestimating the acid potential.

The number of samples selected must be sufficient to be representative of the mineable reserves. Samples should be selected from a number of drill holes and should represent intervals no greater than 10 metres and preferably about 5 metres.

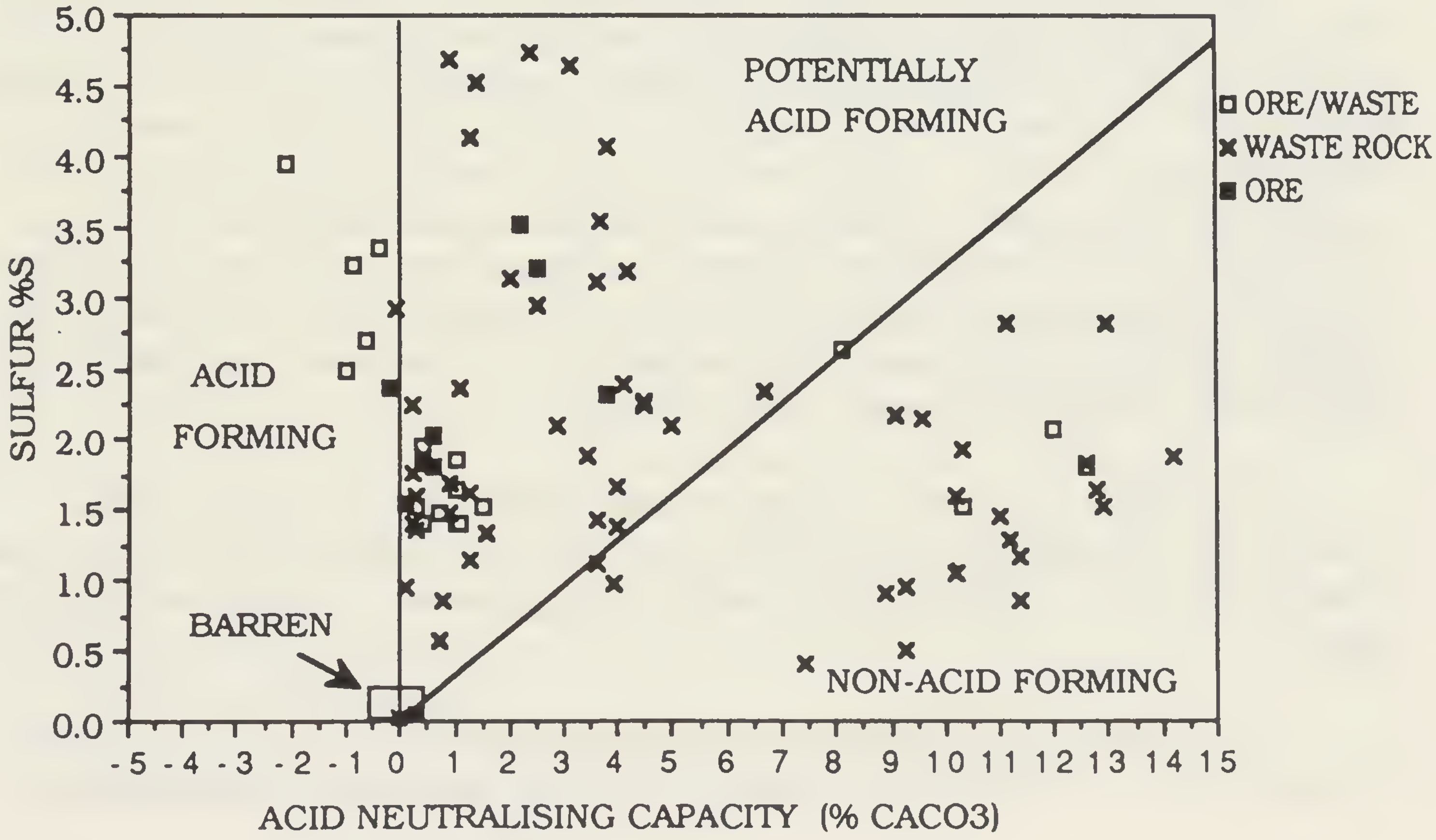
There is no "standard" approach for determining the acid forming potential of mine rock and tailings. However, the acid-base account is commonly used along with kinetic procedures such as column and batch leaching tests.

The approach we have adopted for mining operations in Australia and the Asian/Pacific region is generally two staged. The first stage is the basic characterisation and includes determination of:

- paste pH and electrical conductivity;
- total sulfur; and
- acid neutralising capacity (ANC).

The initial classification of waste rock types is based on the total sulfur and ANC and is determined by plotting the sample results on an acid forming potential classification diagram as shown on Figure 1. The data points plotted on Figure 1 are from a proposed gold mining operation in Indonesia. Four geochemical rock types are identified on Figure 1. These are Acid Forming, Potentially Acid Forming, Non-Acid Forming and Barren.

FIGURE 1: ACID FORMING POTENTIAL



For the initial classification, the boundary between non-acid forming and potentially acid forming rock is based on the balanced acid-base account, i.e. the acid potential from oxidation of the sulfur (assumed all pyrite) is equivalent to the determined ANC. Samples are analysed by the net acid generation (NAG) procedure to confirm if acid generation is possible in the potentially acid forming material and to refine the boundary line between the non-acid forming and potentially acid forming rock types. The NAG procedure involves the addition of a hydrogen peroxide solution to the material, and after reaction, the pH and acidity are determined on the suspension. Generally this results in the boundary line (shown on Figure 1) moving up (i.e. increasing the non-acid forming zone), however, we have had experience with materials where the line shifts down.

We are currently developing the NAG testing procedure for in-pit identification of particular rock types. Development of the procedure is site-specific and requires laboratory calibration to determine the most suitable sample preparation procedure, sample-to-solution ratio, hydrogen peroxide strength and reaction time. The NAG test provides a relatively quick assessment of the acid forming potential of mine rock. In most cases, it appears that a simple pH determination after a reaction period of between 1 and 10 hours is adequate.

An important consideration in material classified as non-acid is that selective dissolution and leaching of carbonates may eventually lower the ANC resulting in long term acid generation. However, this is only likely to occur where the sulfur level is greater than two or three percent. Column and batch leaching tests can provide an indication of any significant preferential dissolution.

The exposure time required (or lag period) for a material to become acid is also an important consideration for waste rock and tailings management. Generally, the period of oxidised leaching required to generate acid conditions increases as the ANC increases. Also, the capacity for acid generation increases with increasing sulfur content. Prediction of the lag period likely in the field from the results of laboratory test is difficult and requires careful assessment. However, indications can be provided from column and batch tests. Also, monitoring the pH and temperature during the NAG test provides data on the reactivity of the sulfides and, as our data based is expanding, the correlation between NAG tests, column tests and field behaviour is improving.

Depending on the mineralogy and the physical characteristics of the material, the lag period can vary from a few months to more than 50 years. Even in waste materials with 30% sulfide sulfur, the lag period can be more than 10 years.

Assessment of acid generation in tailings is based on the same procedure as for waste rock. In CIL/CIP gold tailings and heap leach waste, lime addition results in an initial pH of 10 to 12 and acid leachates are unlikely during the operating phase.

Tailings solids generally range from sand to clay sized particles thus exposing a large surface area for leaching and oxidation. Therefore if oxygen and water are able to contact potentially acid forming tailings solids, oxidation and acid generation will occur. However, even under conditions of oxidised leaching acid generation may not occur until many years after the operation has ceased.

For long term control of acid generation in tailings, it is necessary to prevent free oxygen from entering the tailings mass. This can be achieved by placing an oxygen consuming cover over the tailings such as a compacted seal and active soil profile or flooding the tailings to produce a lake/wetland environment. In wet environments, the option of creating a lake and therefore maintaining the tailings in a saturated condition is a feasible option. Placement of tailings permanently under water, either beneath the ocean or under large natural lakes and dams, will prevent acid generation, and in some situations this option should be seriously considered.

Fate of Cyanide in Gold Tailings

The chemistry of cyanide in a gold tailings system is highly complex and its study is limited by analytical constraints.

Untreated tailings liquor normally contains between 100 and 500 mg/l total cyanide (as CN) although greater than 1000 mg/l are possible. The behaviour of this cyanide in the tailings storage, both in the supernatent (or decant) and associated with the entrained water seeping through the tailings mass, depends primarily on the nature of the cyanide complexes and site climatic factors including temperature and sunlight.

The nature of the tailings solids also has a major impact on the behaviour of the cyanide, particularly if the pH of the liquor is reduced or the content of cyanide soluble iron is significant. The relationship between molecular hydrogen cyanide (HCN) in water and the cyanide ion (CN^-) is strongly pH dependent and at pH 7 almost all the free cyanide will be present as HCN. However, HCN has a high vapour pressure and will volatilise from solution under atmospheric conditions. In general, reduced liquid-depth to surface-area ratios in tailings storages, decreased pH, increased temperature and increased turbulence will accelerate volatilisation of cyanide. A decrease in pH may occur in tailings water due to natural carbonation and can be accelerated by thiocyanate (SCN) hydrolysis if this form is present (sulfide tailings).

The cyanide in the tailings liquor as it reports to the storage normally contains free cyanide (CN^- and HCN), simple compounds (e.g. NaCN, CuCN) and weak, moderately strong and strong complexes. The moderately strong and strong complexes are a major concern since they are relatively stable but can dissociate under certain conditions releasing toxic free cyanide and the associated metals.

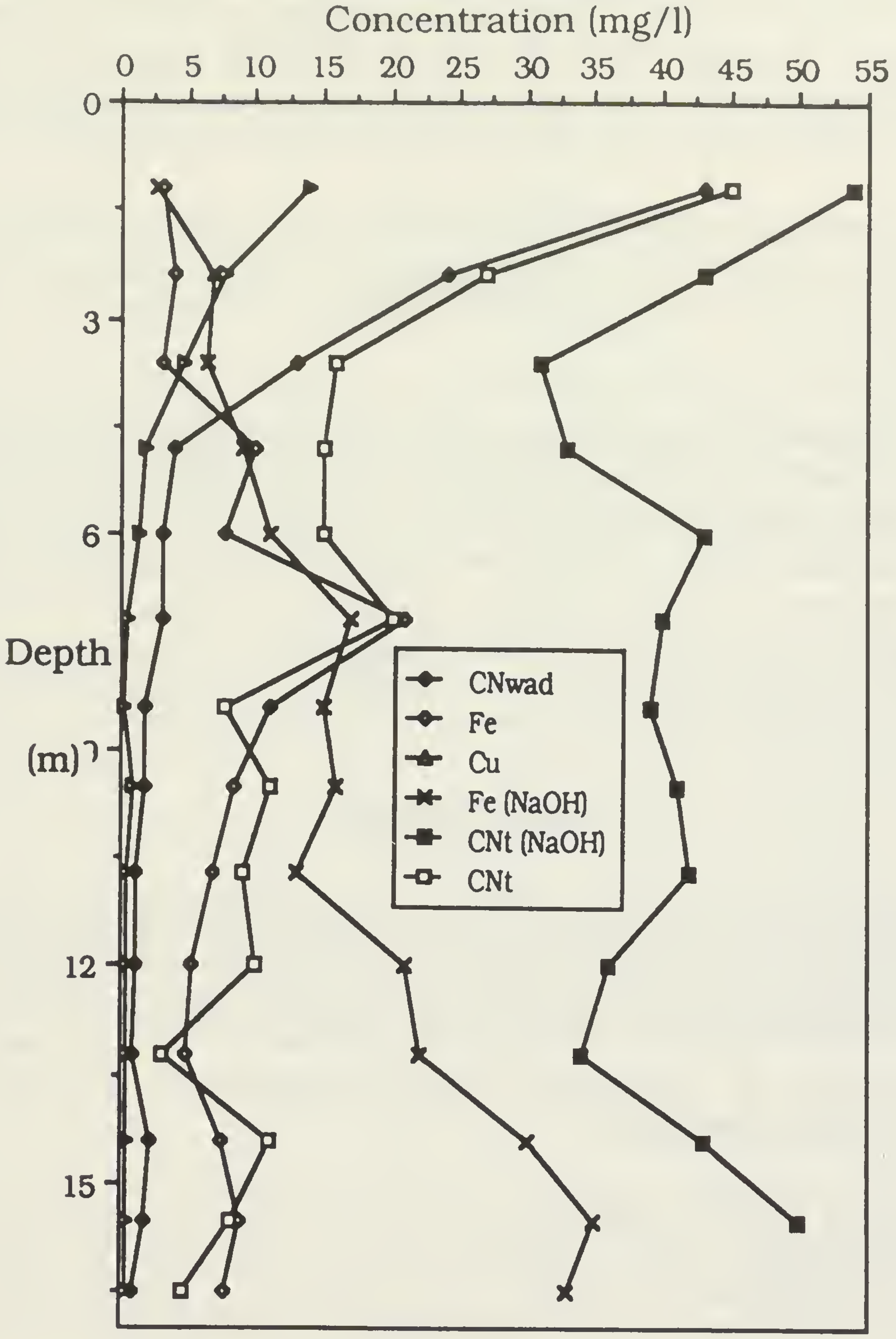
The common copper cyanide complex ions ($Cu(CN)_2$- and $Cu(CN)_3$-) are moderately strong complexes and can be a problem for water treatment and long term seepage. On the other hand, certain iron cyanide complexes are chemically stable and have a very low solubility. For example, a saturated solution of $Fe_4(Fe(CN)_6)_3$ contains only 0.13 mg/l of total cyanide. In gas works waste, iron cyanides are a common waste product and have remained at percent levels in the soils for 50 to 100 years with negligible effect on groundwaters. It should be noted that for redevelopment of gas works sites in Australia, 50 mg/kg total cyanide is the trigger level for concern if the land is to be redeveloped to houses with gardens and 500 mg/kg is the trigger level for redevelopment to industrial uses. Fresh tailings slurry generally contain less than 500 mg/kg CN.

In old gold tailings in Victoria, Australia, testing of tailings treated with cyanide in the 1940's demonstrated levels up to 50 mg/kg total CN. However, cyanide was not observed in drainage from these areas indicating that the residual cyanide is present as stable complexes.

The leaching of cyanide from tailings is generally not a problem because of the very low solubility of the stable complex cyanides and the natural degradation and attenuation of the more mobile cyanides which occurs along seepage pathways. However, rapid migration of significant levels of cyanide has occurred from some sites resulting in environmental problems such as livestock and fish kills. These problems only occur at sites where engineering design and/or operation has been inadequate and major seepage paths occur along faults, in fracture zones or through highly permeable basement materials.

A current investigation carried out by the author to determine the cyanide behaviour within an active tailings empoundment in Australia, has highlighted the capacity of the tailings to attenuate cyanide and metals. Seven depth profiles were sampled and analysed for a number of parameters. Figure 2 shows the generalised trend in the entrained liquor chemistry through the current residue storage. The figure shows the average results for water soluble Fe, Cu, CNwad and CNtotal and NaOH extractable Fe for the seven profiles. The depth-concentration relationship shown on Figure 2 was consistent for each parameter at each site. 1:5 extractions were carried out on "as received samples" and the entrained liquor concentrations calculated. The NaOH extraction was carried out to remove any fixed or adsorbed species soluble under strongly alkaline conditions.

FIGURE 2 : ENTRAINED LIQUOR CONCENTRATION AVERAGE PROFILE



The results of the profile investigation highlight significant reduction in CN and Cu concentrations with depth. Rapid reduction occurs within the upper three to four metres of the profile. This trend suggests that volatilisation of HCN from the surface and precipitation of CuCN may be the dominant process in this zone.

Below about three metres, the decrease in CNtotal concentration is reduced relative to that observed for CNwad. Also, the Fe concentration increases; however, the Cu levels continue to decrease. This behaviour suggests that chemical alteration is occurring whereby the copper-cyanide complexes and other cyanide forms are interacting with the contained Fe resulting in the formation of stable iron-cyanide complexes.

At depths below approximately eight metres, adsorption or precipitation of iron-cyanide complexes onto the tailings solids is apparent since the concentration of water soluble Fe decreases while the content of NaOH extractable Fe increases. The concentration of NaOH extractable CN was also greater than the water soluble CN at depth which reflects the presence of stable iron-cyanide complexes.

The dominant geochemical processes observed, and the resulting Cu and CN concentrations, appear to be a function of depth and/or ageing. Consequently, the deeper the profile, the lower the concentration of CNwad and Cu in the entrained liquor.

These field results show that this active residue storage is effectively immobilising Cn and Cu without any need for additional engineered seals or other treatment. Almost complete reduction of Cu and Cnwad occurs within eight metres of the residue surface with rapid reduction in the upper four metres. The resulting seepage from the base of deeper residue would therefore be expected to contain negligible levels of Cnwad, Cu and other metals. Routine groundwater monitoring data has confirmed the low concentrations of metals and cyanide.

CONCLUSIONS

Acid generation, leaching of waste rock and tailings and the behaviour of cyanide in tailings are the two major geochemical considerations for design and management of waste disposal at gold mining and processing operations. These geochemical processes represent the potential mechanisms for environmental contamination both in the short term (during operational life) and in the long term (following decommissioning).

These issues must be considered on a site-specific basis as many environmental and mineralogical aspects influence the rate and nature of geochemical processes. This is particularly relevant to the indicated lag period required for acid generation and the implications of this for waste management. In addition, the ore mineralogy determines the composition and nature of metallocyanide complexes in the tailings which may have design and long term management implications.

A practical approach to assessing the geochemical characteristics of waste materials and communicating the engineering implications to the design and management personnel are essential for the development and operation of an environmentally sound waste disposal scheme.

RECLAMATION PLANNING FOR OIL AND GAS FIELDS

Tom Lahti[1]

ABSTRACT

Oil and gas activity began in Rocky Mountain Region during the early 1900's. Many of the early fields are still producing today. During the initial development of these older fields, little emphasis was placed upon environmental protection activities and reclamation of disturbed areas. Today, many of the "older fields" continue to change without a plan for environmental protection and reclamation.

Reclamation of producing fields should begin immediately after a well site is equipped for production. Disturbed areas, no longer needed for operations, should be recontoured and revegetated to stabilize the site and reduce erosion. The Wyoming Bureau of Land Management (BLM) has developed a planning process for use by petroleum industry representatives, in conjunction with the BLM, whenever they are proposing expansion of new fields or planning the reclamation of existing disturbances. The procedures contained in this planning process can help resolve conflicts while guiding operators as they develop reasonable measures to mitigate the impacts of oil and gas development and production.

The oil and gas operators, working with the BLM, or other land management entities, should establish a planned priority schedule for completing necessary maintenance and reclamation-related field work. This plan will help the operator budget his resources and work with the land manager to meet present and future responsibilities for environmental protection, reclamation, and final abandonment. Development and implementation of a field reclamation plan encourages the operator to condition a field for reclamation prior to final abandonment.

The primary objective of this paper is to describe a procedure for the development of oil and gas field reclamation plans. This procedure establishes guidelines for reclamation planning of existing oil and gas fields on the Bureau of Land Management administered public lands in Wyoming.

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INTRODUCTION

Advanced planning for oil and gas fields helps the operator condition the field for reclamation prior to final abandonment. This effort helps to relieve the "financial end loading" that normally takes place when an oil and gas field is permanently shut in upon completion of production operations. Providing for funding for proper reclamation and abandonment can become more costly when a company no longer has equipment on site and an active budget based upon production in the field. An Oil and Gas Field Reclamation Plan can get the surface manager and the operator together to help guide concurrent reclamation activities while an oil and gas field has employees on site, when there are equipment and materials available, and when the field is still producing income for its operator.

THE PLAN

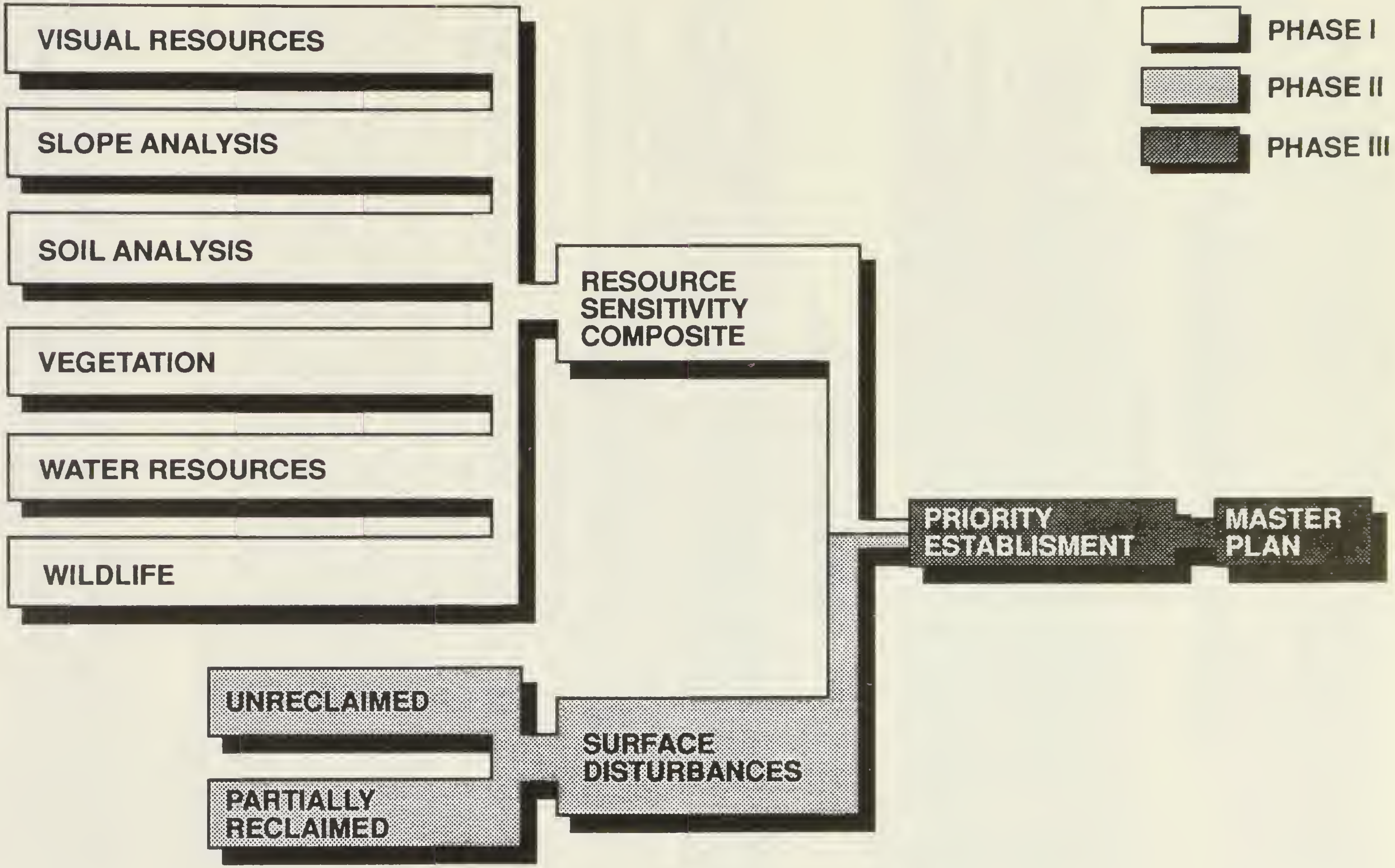
The overall goal for an Oil and Gas Field Reclamation Plan is twofold. First, to get the surface management agency and the operator to work together to reduce the surface disturbance related impacts of the field through reclamation concurrently with production. Second, to help the oil and gas company reduce its overall reclamation liability during the "money producing stages" of the field in order to avoid the "end loading" of major expenditures upon abandonment.

Objectives of the reclamation plan include the following:

- initiate the reduction of surface disturbances in the oil patch;
- identify the necessary stabilization/reclamation work by priority;
- provide a cooperative atmosphere for conflict resolution and joint ownership in the final reclamation effort; and
- help conduct this reclamation activity within the budget constraints of the oil and gas production company.

The reclamation planning process is basically a simple three-phase process, illustrated on page 3. Phase I involves an inventory of the resource values in the area, an analysis of their priorities, and establishment of high, medium, and lower priority resource values. Phase II requires a detailed field inventory that identifies all disturbances and facilities, maps their location, and describes recommended remediation. Phase III involves the integration of Phases I and II in order to establish a plan with priorities for all work to be completed. It also mandates the

OIL AND GAS FIELD RECLAMATION PLANNING



Wyoming Bureau of Land Management
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development of a formal agreement between the operator and the surface management agency describing a schedule, timeframes, and corporate commitment toward the reclamation plan.

PHASE I - RESOURCE INVENTORY

Slope Analysis

Slopes are crucial considerations in facility planning. Flat slopes lend themselves to most types of construction, but may create drainage problems. Steep slopes create construction problems, higher potential for erosion, and, thus, difficult reclamation procedures. The slope analysis should demonstrate which areas will have high potential for erosion on existing surface disturbances and provide information that will be used as a guideline for reclamation standards and specifications.

Soils/Geotechnical Analysis

Soils and geotechnical resource information is crucial to the resource inventory. Soils and surficial geology constitute the medium in which construction, reclamation, and maintenance occur. Soils and surficial geology in concert with other site factors will determine if a site is suitable, moderately suitable, or unsuitable for specific uses. These characteristics will describe the limitations of each site and therefore enable accurate site specific planning and engineering design for development, reclamation, and maintenance.

Soils and surficial geology data should be used to understand soil suitability for planning, locating, and developing new improvements such as roads, drilling pads, pipelines, reservoirs, borrow sites, waste disposal sites, etc. This data will help identify areas where problems will be critical to safety and the environment. In such cases, more testing and additional engineering will be required. The inventory should help classify soil mapping units by their erosion susceptibility and revegetation potential. This will enable the operator to prescribe specific construction and revegetation practices for each soil mapping unit. In addition, the soils and surficial geology information should help identify potential aquifer recharge areas, potential borrow areas, general slope instability, and other hazards as may be apparent.

In addition to the agronomic soil survey, an engineering soil survey should be conducted concurrently. It is important, as certain conditions exist, the depth to seasonal high water table, unified classification, and depth to bedrock particularly with regard to the "C" horizon and substrate or regolith material, be accurately determined.

Water Resources Analysis

Water resources are important for several obvious reasons. Streams are impacted by pollution from both on and off site runoff. During oil and gas exploration activities, harmful fluids and gases could contaminate surface water and groundwater resources, and if such resources are located in aquifer recharge areas, subsequent pollution to the aquifer can result.

The construction of support facilities increases erosion. Eroded materials accumulate in or near streambeds. Large amounts of alluvium can affect valuable meadow and stream buffer habitats. Additional silt load can create a change in the physical and chemical properties of the water and streambed.

The water resources analysis should provide data that assists in developing proper reclamation guidelines for sedimentation control until the area reaches slope and vegetation stabilization.

Vegetation Analysis

A vegetation inventory should be conducted on the adjacent undisturbed landscape to help determine revegetation objectives for cover. Data describing plant composition, density, and general cover characteristics should be collected to help characterize the area.

Wildlife Analysis

The major objective in mapping wildlife resources is to identify and regulate those zones within the unit where oil and gas exploration may seriously disrupt habitat or impact normal wildlife activities within the area.

Surface disturbances directly affect vegetation cover that provides wildlife habitat. Reclamation efforts should be geared toward reestablishment of native vegetation losses. While vegetation has been mapped, critical wildlife areas call attention to those areas where wildlife and vegetation are simultaneously critical. In addition to land surface considerations, riparian systems with critical fish and wildlife species must be protected and/or reclaimed as quickly as feasible.

Mapping Visual Resources

The primary objective is to determine those areas where the public has visual access to disturbance, and has a significant adverse impact on its visual quality. These areas should be identified and the overall area's visual quality established. Mitigation measures must then be developed to reduce these adverse impacts.

Resource Sensitivity Composite

All the resource overlays, including slopes, soils, water resources, vegetation, wildlife and visual resources should be cross-referenced to graphically portray a range of sensitivity levels for each resource. The purpose of the Resource Sensitivity Composite is to bring each of the overlays together into a single drawing that will illustrate all the ranges of sensitivity within the area (see illustration on page 7). This drawing is particularly valuable when assessing environmental problems that help establish site specific reclamation objectives for the area. If a proposed development falls into a sensitive area, the compliance officer is able to quickly assess the nature of potential problems and propose guidelines that will enhance future reclamation.

PHASE II - FIELD INVENTORY

Conduct a field inventory, record all disturbances and facilities, then recommend solutions for environmental problems on each. Record them on two forms, the Field Base Map (page) and on the Maintenance and Reclamation Log (page).

Major Surface Disturbances

Major surface disturbances resulting from oil and gas exploration and development include: drilling/producing locations (well site), roads, pipelines, tank batteries, powerlines, and pits. The following includes a brief description of these common facilities and their disturbance.

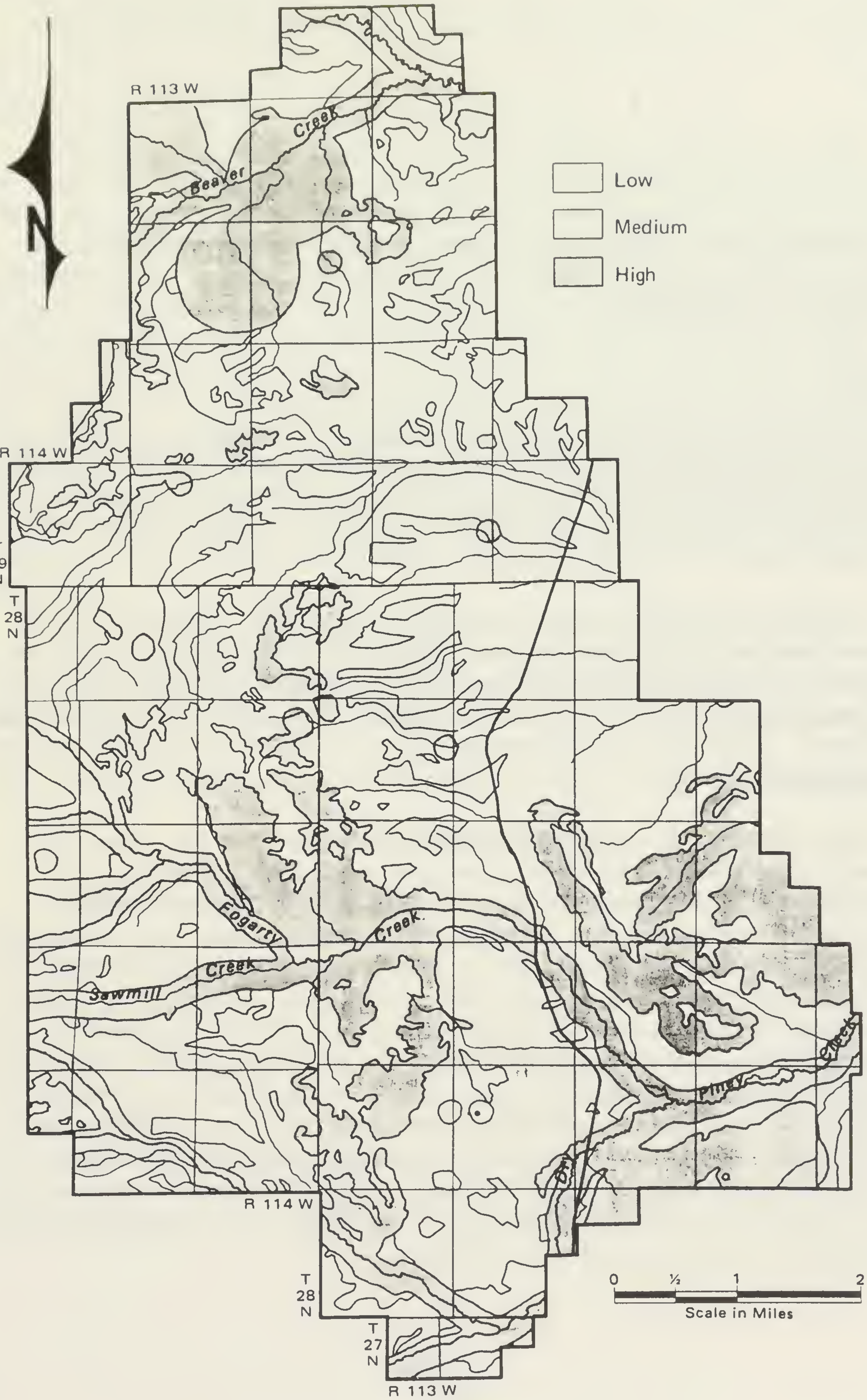
Locations

The original location serves many purposes during exploration and production. During exploration, it serves as the pad for the drilling equipment. If the well becomes a producer, the location will provide space for pump jacks, well head equipment, tank batteries, and pits. Locations usually vary in size from two to six acres. Most are flat. Although the location is generally flat, a gentle slope helps drain surface water and keeps the location from accumulating water.

The greatest impact from a location stems from the fact that it is often constructed in steep terrain, resulting in significant amount of surface disturbance.

When a discovery is made, production facilities are placed on the pad. These facilities may include the well head equipment, pump jack, and various facilities that refine the petroleum product produced on site. When a well

ENVIRONMENTAL SENSITIVITY COMPOSITE



becomes a producer, it may be many years before the site can be completely reclaimed. However, after the drilling is complete and the production equipment installed, some reclamation can begin outside the area needed for production.

Roads

Roads pose special problems. They are usually present for extended periods of time. Single operators are responsible for each location, but many operators may use the access road. It is often difficult to determine responsibility for the maintenance and ultimate reclamation of the road. Therefore, proper location and construction of all roads are vital when maintenance and eventual reclamation are considered.

Pipelines

Pipelines are often used to collect and transport oil and gas produced in a field to a central gathering facility, then transport the product to refining facilities and/or distribution networks. Pipelines may also be used for other production purposes such as water transportation in fluid injection, disposal of produced water, etc.

Pipelines occasionally break, creating localized spills. Improper backfill activities often result in unnecessary settlement along the pipeline. This creates high potential for erosion and makes revegetation difficult. Since the lines are usually straight, their visual impact can be significant, especially in rugged terrain.

Tank Batteries

Tank batteries are facilities used to collect and store crude oil and other hydrocarbons produced in the field. They can also house equipment used to separate oil and water if large amounts of water are produced with the oil. Heater treaters used to separate the oil and water mix are commonly located near a tank battery. The tanks and treaters must be placed on a level area having adequate drainage. For safety purposes, the tanks and treaters must be placed certain distances from each other. Spill prevention dikes are constructed around tanks to prevent spilled material from leaving the site. If the products are trucked from the field, the battery also serves as a load out. The tank battery can be a relatively large site, depending on the number of treaters, tanks, access roads, or other equipment present. Fire is a major concern at a battery. Therefore, vegetation is usually kept out of certain areas on the site. Many of the improvements at a battery are visually obtrusive since their color, form, and texture do not always blend with the surrounding landscape.

Powerlines

In unforested situations, powerlines do not greatly alter the natural environment. Vegetation below three feet is often left relatively undisturbed. However, the right-of-way is generally cleared in forested areas. In the latter case, the impact is greater and can have a long-term influence on the area.

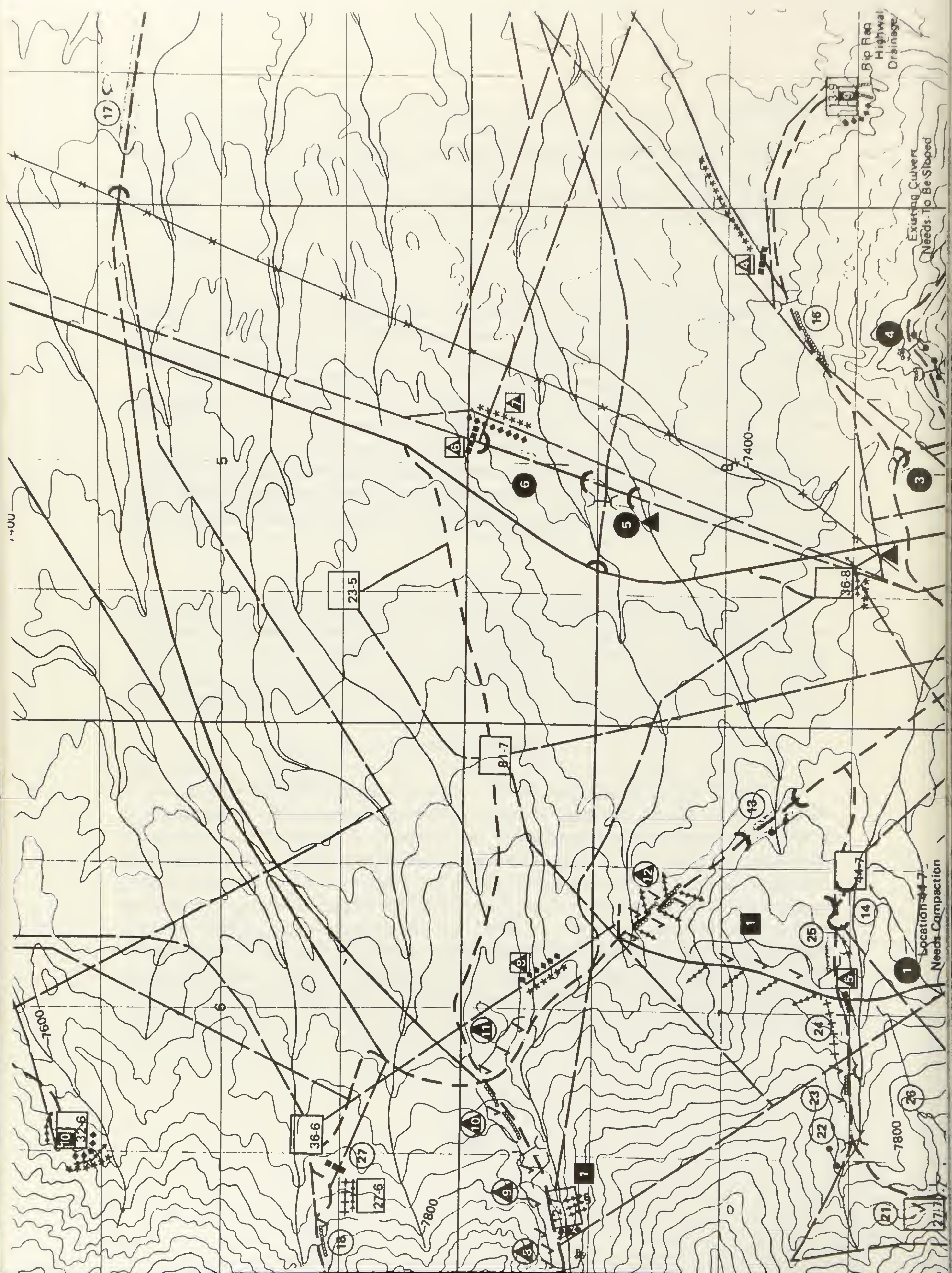
Pits

Pits serve several purposes in the oil patch. Reserve pits (mud pits) are constructed during drilling. They are usually excavated earthen-walled pits, designed to contain fluids and solids that flow from the well during drilling. Their size depends on the anticipated depth of the hole, type of mud system used, anticipated water flows from the hole, geology, etc. The nature of the materials within a reserve pit creates a high potential for environmental impact if they are not properly contained. The solids placed in the pit are primarily hole cuttings and drilling mud. Although the mud is mostly water and clay, additional drilling fluid additives are often used. These additives can be toxic to plants and must be properly disposed of on, or off site. In addition, because of its slow drying time, a reserve pit, especially one at high altitude, can pose long-term reclamation problems.

In a producing field, large amounts of produced water are often encountered. When this occurs, water storage pits are constructed downslope from the tank batteries. The water can be discharged on the surface if proper permits are obtained, or it may have to be stored for reinjection or evaporation. Considerable surface area can be required for pits if large amounts of water are produced.

Field Base Map

The individuals conducting the inventory are to verify and identify each disturbance by adding, deleting, or amending information from the aerial photography and company field maps as they are recorded on the field base sheet (see illustration on page 10). When a disturbance having no evident problems or which has been totally reclaimed has been identified, it should be noted, traced in blue on the mylar overlay, or black if it is a road that is in no need of maintenance. If a problem does exist, it should be noted (trace the disturbance in orange) and assigned a reference number to the disturbance for explanation on the logsheet. When the disturbance poses an imminent safety hazard or presents significant environmental damage, it should be noted, (traced in red) and also given a reference number.



17
10
32-6
7600
36-6
27
27-6
18
7800
6
9
8
12
1
10
11
23-5
81-7
5
6
7
6
5
7400
36-8
12
13
1
25
14
44-7
5
24
23
22
26
21
7800
1
Location 44-7 Needs Compaction
3
4
16
4
13-9
9
Existing Culvert Needs To Be Sloped
Rip Rap Highwall Drainage

Maintenance and Reclamation Logsheet

All disturbances will fall into either a "maintenance problem" or a "reclamation problem" category. A maintenance problem is any situation or facility that needs attention to ensure continued use. One of the most prevalent maintenance problems is erosion occurring on a road base or in a road ditch. A reclamation problem is any situation that needs attention to ensure successful reclamation. It may be difficult to distinguish between a maintenance and a reclamation problem on areas being reclaimed. Determine the cause of a particular problem. If erosion, sedimentation, or decline in vegetation is occurring on facilities in use at the time, then it becomes a maintenance item. However, if the problem is the result of poor or lack of reclamation practices, then it is classified as a reclamation problem. In all cases, the decision lies with the field worker as to the appropriate category, but the main objective is to ensure that work be done in priority order, to satisfy both needs. Use an "M" for maintenance problems or an "R" for reclamation problems in the appropriate column on the Logsheet.

The distinction must be made between unreclaimed and partially reclaimed disturbances to help establish priorities for required work. The partially reclaimed classification may include one of the following criteria:

- incomplete reclamation;
- disturbed areas that are not in use and which have begun to revegetate naturally; and
- reclamation efforts which have failed such as a waterbar breached where erosion is occurring, or if additional water management measures are needed because too few were used initially.

The unreclaimed classification includes any situation meeting any of the following criteria:

- no previous reclamation work has been done;
- facilities currently being used; and
- areas where attempts at reclamation have failed.

Since a totally reclaimed disturbance should be stable and basically free of problems in the field, there is no need to enter the reclaimed disturbance on the Logsheet. However, the other classifications are to be recorded with a "P" in the "classification" column for a partially reclaimed situation and a "U" for those that are considered to be "unreclaimed". The status of each situation must be determined by the person conducting the inventory.

Note the type of environmental disturbance. Record "L" for locations and add the location number for each well; "R" for roads; "P" for pipelines; and "M" for miscellaneous types of disturbances. Discuss each situation and recommend a solution. Place numbers of the solutions corresponding to the graphic legend on the back of the Logsheet. Then enter notes and graphics concerning the solution of each particular problem. This may include, but not be limited to: spacing of particular erosion control structures, materials to be used, and specific locations of control elements. All recommend solutions should also be recorded in the appropriate locations on the Field Base Map as it corresponds to the logbook. See sample Logsheet and Legend (pages 13 and 14) for guidance when documenting field inventory.

PHASE III - WRITING THE PLAN

Following the field inventory, the logbook must be edited and conditioned for final decision making regarding a reclamation plan. The remediation of priorities for each disturbance must be established. The chart on page 14 along with appropriate mapping symbols, establishes the process for establishing priorities. The logbook information is then typed onto two lists, maintenance and reclamation, with the highest priority listed first in each case. The solution section of the typed logbook is then finalized. On a site specific basis, decisions are made in both the field and later in the office as to the use of appropriate BLM standards and specifications. Draft the graphics on logsheets according to the above standards and specifications. A final Oil and Gas Field Reclamation Plan can then be produced.

The operator and the surface management agency shall earnestly enter into negotiation to reach an agreement whereby the solutions to the stated problems enumerated on the Oil and Gas Field Reclamation Plan will be executed in accordance to their associated priority, in accordance to specified methods and materials, and within the agreed schedule of completion. During the planning process, the following items must be addressed.

1. The completion date for each item will be established.

2. Any problem identified as a safety hazard and brought to the attention of the operator, must be attended to by the operator without

MAINTENANCE & RECLAMATION LOG

UNIT ______________________ PAGE ______________

NAME ______________________ APPROVED BY ______________________ DATE ______________

DISTURBANCE						PRIORITY	PROBLEM		TYPE	SOLUTION/MITIGATION	COMPLETION DATE	CHECKED BY
REFERENCE NUMBER	LOCATION	MAINTENANCE/ RECLAMATION	CLASSIFICATION	ENVIRON/VISUAL SENSITIVITY	TYPE		TYPE	SITUATION		DESCRIPTION		

LEGEND

Disturbance Symbols

———	Paved Road
— — —	Gravel Road
[36-6]	Location
— —	Pipeline
—×—×—	Fence
▲	Production Facility

Solution Symbols

)—(	Culvert
⟍	Relief Culvert
++++++++	Water Diversion
oooooooo	Rip Rap
——·-·-	Abandon
■■■■■■■■	Barrier
✱✱✱✱✱✱✱✱	Benching
§	Slope Reduction
	Road Base
)	Crowning
*********	Reseeding
◆◆◆◆◆◆◆◆	Recontouring
✓	Check Dam
⏚	Sediment Filter
⊢+++++++	Ditching
++++++ ═══	Slope Drain
●—●	Sediment Trap
≻—	Headwall

Priority Symbols

○	Maintenance Priority
□	Rehabilitation Priority
● ■	Work to be done within 1 year
▲ ▲	Work to be done within 2 years
◐ ◧	Work to be done in 3 to 5 years
○ □	Work to be done after 5 years

Numbers indicate priority

Priority	Classification	Env./Vis. Sensitivity	Type
S	Safety		
1	U	3	L
2	U	3	R
3	U	3	P
4	U	2	L
5	U	2	R
6	U	2	P
7	U	1	L
8	U	1	R
9	U	1	P
10	P	3	L
11	P	3	R
12	P	3	P
13	P	2	L
14	P	2	R
15	P	2	P
16	P	1	L
17	P	1	R
18	P	1	P

unreasonable delay. This includes those problems enumerated and so designated or which may be detected following the date of agreement.

3. Check off work as it is accomplished. Also, any new problems should be noted on separated logsheets. This can be accomplished during the normal compliance work being conducted on any field. However, it is recommended that the entire field be inspected using the plan at least once a year. This will ensure that scheduled work was accomplished, new problems (which should be minimal) are noted, and new safety hazards are recorded and dealt with as soon as possible. Although the Oil and Gas Field Reclamation Plan may establish general reclamation schedules for five or more years in advance, a detailed two-year plan should be maintained annually by the operator and the surface management agency.

Planning, Rehabilitation, and Treatment of Disturbed Lands
Billings Symposium, 1990

CONSTRUCTION MANAGEMENT: THE KEY TO SUCCESSFUL RECLAMATION

Gary D. Bauer, P.E.[1]

ABSTRACT

Successful reclamation begins at the time of the initial project proposal. For surface disturbing activities proposed on public lands, environmental documentation in compliance with the National Environment Policy Act (NEPA) is the key step in determining the preferred alternative.

Detailed project design proceeds based on the original proposal as modified during NEPA compliance and guided by environmental concerns and mitigating measures resulting from NEPA documentation.

The investment in time and money to complete proposals, NEPA compliance, and detailed design is compromised unless sound procedures for project management and, specifically, construction control are established up front.

During development of the Exxon LaBarge Project in southwest Wyoming, a "self-monitoring" construction control procedure has jointly developed by industry and public land management agencies. This approach proved highly successful in implementing the project's "design for reclamation" philosophy and serves as a successful demonstration project for management of large proposals in sensitive environments.

This paper describes the self-monitoring system utilized, provides an overview of the LaBarge Project parameters, and presents an analysis and summary of the results. Experience with the LaBarge Project confirms the importance of comprehensive project planning/design coupled with sound project management and construction control procedures. The foundation for design-/construction is interactive use of NEPA (environmental) documentation.

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INTRODUCTION

Problem Statement

Projects proposed and authorized on public land vary widely in scope and complexity but share one thing in common; they require a substantial investment in location, design, and National Environmental Policy Act (NEPA) compliance and formulation of conditions of approval (stipulations). The value of this investment, by both government and industry, is compromised if construction of the facility does not comply with the approved design.

In the past, significant projects have been permitted with insufficient attention to plans and monitoring of construction for compliance. Noncompliance may mean failure to comply with key requirements of decision documents generated from Environmental Impact Statements (EIS) or Environmental Assessments (EA). In real terms, this can mean the difference between a reclaimable temporary disturbance and a long-term adverse impact, particularly in sensitive areas (e.g. unstable soils, riparian environments, steep terrain).

Lack of proper construction control is, all too often, the missing link in the steps toward a properly constructed project on public lands. Construction control is that important process of defining the approved plan on the ground, (via construction survey and staking), coupled with a follow-up compliance monitoring program.

The Solution Starts With A Plan

To build something...anything, you first need a plan. Public land management agencies are evolving away from approvals based on narrative project descriptions and long lists of conditions of approval, in favor of actual construction plans and drawings which more clearly define the project and reduce the number of stipulations. BLM's "Rights of Way Handbook" (BLM 1984) for example, was a major step in the right direction. For the first time, significant program-wide guidance recognized that a "picture is worth a thousand words". Regardless of the proposal, the Handbook emphasizes "plans of development" (POD). Theoretically, use of the POD can result in the reduction of an extensive list of conditions to a simple one: "Your plan is approved. Follow your approved plan". In practicality, the POD concept can at least, significantly reduce government imposed conditions and place emphasis on the information contained in the project proposal.

The Rights of Way Handbook recognized that the level of detail of a POD must be consistent with the complexity of the project proposed. A POD may range from a simple narrative project description and map to detailed design plans and specifications. The extent of the POD is left to the judgment of the field specialist and manager. Regardless of detail, the plan describes something to be built on the ground.

The Plan Is Only As Good As Its Execution

Historically, the weakest step in the process has been lack of communication of the approved project proposal to the contractor hired to build it. At this stage, the project already represents a substantial dollar and time investment by both the project proponent and the government. It is here that the investment is either properly carried to completion or compromised (even wasted in extreme cases).

During 1985-1986, an alternative approach to construction control was implemented in western Wyoming on Exxon's LaBarge Project. This alternative to traditional BLM compliance methods proved effective and is described as follows.

EXXON LaBARGE PROJECT

(Review/Analysis of an Industry Self-Monitoring Program)

Background

Exxon's LaBarge Project, located in Sublette and Lincoln Counties in western Wyoming, involved development of a deep gas field (14,000 to 18,000 foot wells) located primarily on lands administered by the Forest Service (FS) and Bureau of Land Management (BLM). Twenty-one gas wells, 3 manifold sites, 39 miles of gathering lines and water lines (multiple pipelines), a dehydration facility, a 39-mile sour gas (hydrogen sulfide) trunkline, a gas conditioning plant, 93 miles of access road (new and reconstructed), and 51 miles of powerline were constructed within or in the vicinity of the well field area. Development drilling activity and limited site construction began in 1984: however, the bulk of well field construction activity occurred between May and November of 1985. The project was substantially completed by September 1986.

Construction, operation, and reclamation of the project was governed by the Riley Ridge Final Environmental Impact Statement (FEIS) and Record of Decision (ROD) (BLM/FS 1983-1984). Prior to beginning construction, Exxon submitted and received approval of overall Construction and Use Plans and site-specific plans, which collectively constituted a complete Plan of Development (POD). Standard field construction survey control governed earthwork activities. The project was controlled by Exxon personnel on-site and in Midland, Texas, and permitting and plan approval was conducted by the Bridger-Teton National Forest Supervisor's Office, Big Piney Ranger District, and BLM's Pinedale Resource Area and Rock Springs District.

Self-monitoring of project activities occurred through an organized Quality Assurance/Quality Control program.

What Is Quality Assurance/Quality Control

The Quality Assurance/Quality Control (QA/QC) concept is not new. QA/QC has been widely used as a construction management tool in industrial and major construction project applications for several years. The concept depends on advance development of plans and specifications governing the work, followed by systematic monitoring of construction activities. The separate but related responsibilities of QC and QC are as follows:

> Quality Control - QC is directly responsible for ensuring that project activities are conducted in accordance with approved specifications and plans. Typically, each major construction operation is observed by a QC Inspector. QC Inspectors are in the general vicinity of their assigned operation on a full-time basis and are charged with determining whether the contractor is in compliance with specifications, procedures, etc. If noncompliance occurs, the QC Inspector takes immediate action instructing the contractor to correct the deficiency. Noncompliance is documented via noncompliance reports (NCR) or, at a minimum, in the QC Inspector's daily log or diary.
>
> Quality Assurance - QA is responsible for determining that the project's QC system is effectively operating to ensure compliance. Typically, the QC Inspector accomplishes this through periodic on-site visits to the various construction sites, audit review of QC records, and dialogue with QC Inspectors. If QA review identifies any problems with the QC system, they are documented and brought to the attention of the Chief QC Inspector for correction. On a typical project, one QC Inspector may cover the same scope of work activity as 10-20 QC Inspectors. To be effective and credible, the QC function must be organizationally independent from, but closely coordinated with, the QC system. QC operates in a daily on-site monitoring mode, while QA's role is typically one of systems review/analysis and record audit. Together, the two form a coordinated project monitoring and oversight function keeping project management personnel informed of the project's progress and overall quality.

The LaBarge Project Quality Assurance/Quality Control Program

Between November 1984 and April 1985, meetings were held between Exxon, FS and BLM to determine the most efficient method of handling the peak permit and construction workload anticipated during the 1985 construction season. Expeditious permit processing was needed to support an aggressive construction schedule and a sound construction control program was required to ensure that field work complied with approved plans. Field compliance was considered critical due to the magnitude of the project development and the sensitive nature of the project area. Based on general guidelines provided by BLM and FS, Exxon designed a self-monitoring program which was approved by the federal agencies. This program consisted of a comprehensive industry QA/QC Program with federal oversight.

Exxon's 1985 QC Program consisted of 58 inspectors under the direction of 15 Field Construction Coordinators and Technical Foremen. These QC personnel were responsible for direct inspection of construction activities to ensure compliance with approved plans and specifications. QA was staffed by five inspectors under the supervision of a Compliance Engineer. The primary responsibility of QA personnel was to monitor the QC program and provide general oversight to the project with emphasis on environmental considerations. Staffing of the QA/QC Program was provided by Exxon and consisted primarily of personnel contracted from various consulting firms in the region.

To interact with Exxon's QA/QC staff in the field, the FS and BLM jointly appointed two Authorized Officer's Representatives (AORs). The AORs (one from each agency) provided seven day coverage of the project on a rotating schedule. The AORs jurisdiction covered the entire well field and feed gas pipeline without regard for the administrative boundary between BLM and FS lands. The primary role of the AOR team was to oversee the effectiveness of Exxon's QA/QC Program and to act on field modifications to approved plans. AOR personnel were delegated responsibility to approve field changes and judge when contact with the appropriate Authorized Officer was required.

The Results

Between May 1985 and January 1986, 6 well sites, 3 manifold sites, 39 miles of multiple string pipeline, 49 miles of road (new and reconstructed), and 39 miles of powerline were constructed in the well field. In addition, the 39 mile feed gas trunkline was substantially completed including construction of 9 miles of permanent access road and 11 pipeline block valves. During the same period, reclamation work was performed on over 1,400 acres of temporarily disturbed lands. This activity required approval of approximately 120 field design modifications.

The experience with the 1985 construction season clearly demonstrated the value of the QA/QC concept as described above. Overall, the system worked effectively and allowed for industry self-compliance with minimal federal involvement in the field. AOR's, as the focal point for field contact with Exxon, provided clear, consistent federal input to the process of construction control. By assuming the responsibility for their own compliance and construction control, Exxon enabled the BLM and FS to handle the massive LaBarge Project without hiring additional personnel. During 1986, the program continued intact with gradual reduction in personnel proportional to the level of field activity. Again, the system proved its value and the project was substantially completed by September 1986.

Analysis Of The QA/QC Program

Due to the potential value of self-monitoring the QA/QC concept for other projects on public lands, a "post-season" review of the system was conducted. The review was based on interviews and reports prepared by the AORs, contact with other BLM and FS personnel involved with the project, and interviews with Exxon personnel and consultants employed in both QA and QC functions on the LaBarge Project.

Based on the above, the following conclusions were evident.

1. The use of a self-monitoring program of this type is valid for large projects such as the LaBarge Project.
2. Success of the concept depends on advance support and commitment by management (both government and industry).
3. The effectiveness of the concept and, to a greater degree, specific activities conducted under this system is directly dependent on the backgrounds, personalities, and qualifications of the individuals involved.
4. The independence of the QA staff relative to the construction organization is an important factor.
5. The concept shows applicability, in modified form, to virtually all proposals for mineral and land development within federal jurisdiction. The benefits of self-monitoring, however, generally increase with project size and complexity and the environmental sensitivity of the project area.

Details of the above conclusions are discussed below.

1. Use of QA/QC and self-monitoring on large projects.

   The use of QA/QC and its many benefits (both in terms of efficiency and promoting user responsibility for field activities) were clearly demonstrated on the LaBarge Project. This approach minimized the number of agency personnel needed in the field and allowed the BLM and FS to handle the workload of this major project without additional personnel. Government field representatives not only provide project oversight, but are available to respond to needs for minor field modifications as they occur.

2. Management support is essential.

   The self-monitoring concept can only succeed if management is committed to the approach and supportive of the personnel involved. Authorized Officers must be willing to trust the judgment of personnel in the field and the project proponent's management must be committed to compliance and self-monitoring. This commitment necessarily includes willingness to alter or even temporarily shut down certain project operations if serious or chronic noncompliance or field conditions require.

3. The concept depends on the people involved.

   Successful implementation of QA/QC self-monitoring is directly dependent on the background, qualifications and personalities of QA, QC and regulatory personnel. Inspection personnel should be experienced in construction and/or project management. Use of the concept will generally make qualified personnel more readily accessible since, 1) experienced personnel are commonly available in the private sector through consultants, and 2) few federal personnel are required to interface with the company's QA/QC organization. This latter point allows Authorized Officers to utilize their most experienced people to handle large projects or several small operations.

4. The importance of QA organizational independence.

   A credible, effective QA/QC system depends on the organizational independence of the QA staff assigned to the project. If both QA and QC report to the same field manager, concerns raised by QA can tend to be discounted in favor of progress or economy. An organizationally independent QA staff tends to result in a "checked and balanced" monitoring system.

5. Applicability of the concept to other types of proposals.

   The formalized QA/QC system of self-monitoring is primarily applicable to large development projects. The self-monitoring concept, however, shows utility regardless of project magnitude. For smaller projects such as a single well and access road, pipeline or powerline, the monitoring organization may be as small as a single full- or even part-time QC Inspector.

   In many cases, self-monitoring can be implemented simply through utilization of industry personnel who otherwise would be on site. At a pre-work meeting, federal personnel can explain the key environmental-/compliance concerns to project management personnel who then act to ensure compliance. A key element of this approach is preparation of an approved plan of development prior to commencement of construction.

Use Of The Self-Monitoring Concept

Self-monitoring is not an across-the-board replacement for traditional compliance methods. It is however, an alternative worth considering in selected situations. The concept is applicable to widely varied situations, however, benefits generally increase with project size and complexity and the sensitivity of the project area. Self-monitoring requires advance planning and coordination, giving consideration to the five items described above.

The concept and general guidelines may be proposed and developed by either the government or the project proponent; however, the actual project compliance organization and staffing should be prepared by the proponent. To be successful, continual constructive dialogue between industry and government must take place and major project issues must be resolved quickly.

Finally, the level of compliance effort must be commensurated with the size and complexity of the proposal. A small project may be handled without additional personnel while large projects may require an extensive formal compliance organization.

Preplanning and commitment by both industry and government are the primary requisites to a successful self-monitoring program.

SUMMARY

Industry self-monitoring, whether through a structured QA/QC program for major projects or via a single full- or part-time QC inspector for smaller projects in sensitive areas, presents an alternative to conventional compliance monitoring. It offers the following advantages.

1. It promotes compliance. The holder or operator has a stake in and a clear commitment to compliance "up front". The traditional "we-they" relationship between government and the user, if present in the past, is diffused.

2. It simplifies accounting and reduces fund transfer amounts on cost reimbursable Rights-of-Way. Project proponents can directly staff the QC (QA/QC on large projects) organization, thereby reducing the cost reimbursable amount charged by the government for project monitoring.

3. Governmental staffing problems for large projects is reduced or eliminated. Private industry, through the use of consultants, contracts or direct hires is better able to cope with the temporary staff increases and subsequent reductions associated with project work.

4. The concept is consistent with current government emphasis on:

    - public land users paying proportionally for their use;
    - reduction in "big government" bureaucracy;
    - government agencies being more responsive to clients (example: AORS in the field can respond directly and quickly to needs for minor project modifications).

5. It is consistent with current government emphasis on Human Resource Management, Project Pride, or similar efforts. Capable employees are afforded the opportunity to function independently,

making decisions for which they are accountable. In addition, the agencies involved can react more positively to the needs of a large segment of their clientele.

In order to realize the advantages of self-monitoring, only minor obstacles must be overcome, namely:

- advance coordination with and commitment by the project proponent and the Authorized Officer. The process of developing trust, rapport and open communication begins during the early stages of the project proposal; and

- Authorized Officers must be willing to entrust field authority to their representatives on a routine basis. Local managers and staff specialists must recognize and accept that other personnel can become involved in getting the approved plans constructed on the ground.

Self-monitoring and the QA/QC system is not a cure-all for field compliance. The approach should not be viewed as a "across-the-board" replacement for past compliance techniques. Clearly, however, it is a valuable tool worthy of serious consideration. Self-monitoring is a proven alternative available for discretionary use by field management.

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ASSESSING REVEGETATION SUCCESS: DO WE HAVE TO WAIT 10 YEARS?

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ABSTRACT

Many federal and state agencies require reclamation of disturbances associated with mining or minerals development and extraction on federal or state lands. Very few agencies have established criteria or goals to assess whether the revegetation efforts have been successful. The Surface Mining Control and Reclamation Act (1977) represents one of the few documented and implemented programs to evaluate reclamation efforts; however, the ten year evaluation period may not be reasonable for other types of activities. Developing a sampling program or identifying key vegetation components that could provide reasonable estimates or probabilities that reclamation efforts will meet a desired goal in ten years would be extremely useful to land managers, mine operators, and others involved in reclamation activities. Reasonable predictions can be made if the appropriate data is available or is collected. Case studies and examples will be presented to show how interim measures of success can provide reasonable predictions of successful revegetation.

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INTRODUCTION

Many federal and state agencies require reclamation of disturbances associated with mining or minerals development and extraction on federal or state lands. As a guarantee that the disturbance is reclaimed, a bond is often required of the mining or energy development company. This bond is based on the estimated costs to reclaim the land if the developer defaults and thus may often be a considerable amount of money. Bonds may represent a significant percentage of the total development costs for certain types of surface disturbing activities such as exploratory wells and access roads.

While the bonds required to initiate mining activities are real, the criteria for determining whether successful reclamation has occurred and whether the bonds can be released are often variable and not well defined. Few agencies have established criteria or goals to assess whether revegetation efforts have been successful. Those agencies that do assess whether reclamation has been successful may have different criteria between different districts or operational groups within the same agency. The criteria that have been established for evaluating success have also been seriously criticized in many instances (Redente et al. 1983).

BOND RELEASE CRITERIA

The Surface Mining Control and Reclamation Act (SMCRA) represents one of the few documented and implemented programs to evaluate reclamation efforts of surface disturbing activities. However, those regulations apply only for surface mining of coal in the United States and may not be reasonable for other types of activities. Certain evaluation criteria contained in SMCRA should be considered for adoption as standards for other types of surface disturbing activities. Kunkel and Hinzel (1983) report that vegetation cover, production and composition were generally accepted as the most suitable characteristics to use in assessing revegetation success. These were identified from a formal questionnaire given to industry reclamation personnel, consulting scientists and agency personnel.

As specified under SMCRA, federal and state agencies have utilized vegetative cover, production, species diversity and woody species density as criteria for evaluating revegetation success for bond release (Mathews 1983). One of the most controversial issues in SMCRA is the requirement to establish a "diverse, effective and permanent vegetative cover" (Emrich 1983). The term diversity in this context is particularly problematic because the term is not well defined. Is it structural complexity, species diversity or spatial heterogeneity (Kunkel and Hinzel 1983). Most agencies interpreted "diverse" as referring to species diversity and recommend using some type of diversity index such as the Shannon-Weiner diversity index. Diversity indices are difficult to interpret and are derived from information theory that does not necessarily reflect the true biotic nature of the vegetation community (Emrich 1983). For these reasons, the use of a mathematical diversity index is not well accepted as a standard for evaluating revegetation success.

Another commonly used standard for determining reclamation success is shrub density particularly for those areas where the post-mining land use is wildlife habitat. Unfortunately, density of shrubs does not bear a direct relationship to the quality of wildlife habitat. Some early attempts to establish shrubs from seed or transplants have also been very disappointing (Crofts and Parkin 1979, DePuit and Dollhopf 1975, Eddleman 1982) and have lead the mining industry to oppose the use of shrub density as a standard for reclamation success. While additional research has improved the success of shrub establishment particularly through the use of transplants (McKell et al. 1979, USDA Forest Service 1979, Long et al. 1984), it still remains as a costly alternative of meeting shrub density requirements for revegetation success.

While the most suitable vegetation characteristics for determining successful revegetation are still highly debated, the fact that bonds are being required and/or being released based on no specific criteria is even more alarming. This has lead to disagreements, mistrust and confusion between mining companies and regulatory agencies. Specified goals of reclamation need to be established for all surface disturbing activities. Most people working in the reclamation field agree that these goals should be based on reasonable post-mining land use of the proposed disturbed areas (Redente et al. 1983, Sindelar and Murdock 1985).

TIMING OF BOND RELEASE

Besides the need for established and documented goals, there is a need for being able to assess the success of revegetation efforts in a shorter period than the ten years required under SMCRA. This is particularly valid for small mining operations with limited resources or for particular post-mining land uses such as agriculture (Friedlander 1983). There are additional problems with a ten year liability period regarding consistency in personnel coordinating and evaluating the success of reclamation efforts. If qualitative judgments are made regarding the suitability of reclamation efforts, then the goal to achieve bond release could change as often as personnel in the regulatory agency change. Developing a sampling program or identifying key vegetation components that could provide reasonable estimates or probabilities that reclamation efforts would meet a desired goal in less than ten years would be extremely useful to land managers, mine operators, and others involved in reclamation activities.

There are three factors that I have observed in my 15 years of experience as a reclamation scientist evaluating successful reclamation projects that make an assessment in a shorter period than 10 years a relatively reliable alternative: 1) species survival generally stabilizes in 3-5 years, 2) symptoms of the failure to reestablish nutrient cycles occurs in 2-5 years, and 3) problems with subsoils, acidification or toxic element accumulations are generally (but not always) apparent in vegetation performance after 3-5 years.

Stabilization of Species Survival

Several researchers have shown that shrub survival decreases rapidly the first one to two years but levels off and stabilizes in three to five years. Van Epps and McKell (1980) showed that transplanted shrubs in a salt desert vegetation type showed significant decreases in plant survival for three years following planting. The survival did not decrease significantly during the next three years at which time monitoring ended. This pattern occurred at all four sites evaluated although the level at which the survival stabilized was different among the sites ranging from 5 to 40 percent. The same phenomenon occurred if one compares individual species or type of plant material (container grown vs. bareroot).

Anderson et al. (1985) showed similar trends in transplant survival from a topsoil filled trench over processed oil shale. Forty-five percent of the plant deaths occurred the first year. This dropped to twenty percent the second year and remained relatively stable the following three years.

In another study, 28 different species of transplant shrubs and trees at ARCO's Sheep Mountain CO^2 drill pads were evaluated for survival for three years following planting. Results showed the greatest losses during the first year with overall survival averaging 59 percent (NPI 1984). After three years, plant losses were still occurring with an overall survival rate of 45 percent. Fourteen of the 28 species showed no losses between the second and third years. A longer period of time (four or five years) may be required before plant mortality stabilizes for some non or marginally adapted species on these types of sites.

Establishment of Nutrient Cycles

The second component that makes an evaluation of the success or failure of revegetation possible after two to five years is that this is the period when nutrient cycles must be functional or nutrient deficiency symptoms start to appear. The Sheep Mountain site demonstrates the impacts of not establishing nutrient cycles. The symptoms associated with nutrient deficiencies vary but are manifested generally by decreased plant vigor and cover along with premature yellowing or reddening of plant leaves. Nitrogen and phosphorus are generally the most commonly exhibited nutrient deficiencies in the western U.S. although potassium and sulfur have also been recorded for revegetation of mine tailings and stored topsoil (Ostler and Allred 1987). The Sheep Mountain site showed decreases in plant cover on all five sites evaluated from the second to the third year. Losses in cover ranged from 1 to 11 percent for the five sites with an average of six percent. The vegetation at the sites, particularly the grasses, showed the characteristics yellowing of nitrogen deficiency.

Evaluations along the Alaskan Pipeline four years following seeding showed serious nutrient deficiencies and loss of plant vigor. While the first couple of years showed excellent plant growth, cover decreased dramatically with the associated loss of plant vigor during the third and fourth years. This occurred in part because the nutrient requirements of the agronomic grasses used for revegetation could not be sustained with the slow turnover and cycling of nutrients in these cold climates. The introduced grass species seeded showed serious phosphorus and nitrogen deficiencies. Unfortunately, no quantitative data was taken during the first two years following seeding. However, comparisons could be made between adjacent areas that were seeded four years previously and sites that were redisturbed and reseeded one and two years previously. The differences in cover and plant vigor were visually obvious.

Occurrence of Soil Related Problems

Failure to achieve successful revegetation can also occur by problems related to the physical and chemical nature of the soil. Tailings from mining operations particularly copper and high sulfur coal have the potential to become acidic in a relatively short period of time. Nielson and Peterson (1972) reported that in two years copper tailings in an experimental area had turned acidic from an initial pH of 7.9, and that by the end of the third year, 75 percent of the area was highly acidic. Another study at Hurley, New Mexico showed that within ten years the pH of the copper tailings had dropped from 8.0 to 2.0. A graph of tailings of various ages at this site showed that in five years the pH had reached approximately 3.0 which is lethal to most plant species.

The harmful effect of the acidification is not solely contributive to the higher H+ concentrations, but has been shown to be influenced largely by the solubility of heavy metals at lower pHs (Nielson 1972, Kabata-Pendias and Pendias 1984). Copper, iron, manganese, zinc and other metals have all been shown to increase their solubility with decreasing pH, some as much as 4-5 orders of magnitude (Nielson and Peterson 1972).

There are numerous procedures that are used to control the acidification process (Skousen et al. 1987). While these should be addressed prior to the acidification process being initiated, this is not done in all cases. The time it takes for signs that acidification has occurred can vary depending on the amount of moisture and oxygen to which the acid-forming material is exposed. However, in many situations the symptoms of acidification are evident in some form within three to five years.

ALTERNATIVE APPROACHES

There are numerous alternatives that could be proposed to address the problem of evaluating revegetation success. Many of these alternatives address what vegetation characteristics ought to be used as standards for measuring success. The alternatives presented here relate specifically to the time period needed to adequately assess whether revegetation efforts have been successful. Two alternatives are presented: partial bond release and early bond release. Both alternatives are based on interim sampling that demonstrates that the trend of a particular vegetation characteristic or combination of characteristics is proceeding toward the post-mining goal at a reasonable rate (this could be 10 or 100 years if that is selected as the target date).

There is sufficient biological information available from past studies and literature to establish general regression equations or trend analyses for plant successional changes in a given region. These trend analyses could predict with a specified level of confidence if a reclaimed site will reach the goal for bond release prior to a ten year period. General trend analyses or regression equations would have to be modified to meet specific environmental constraints of a region or vegetation type, but these changes can be addressed statistically (Gilbert 1987). Once the regression is determined for an area, it could be used for any activity in that area. It can also be continually refined as more information becomes available. Unique equations may be required for each post-mining land use. For example, a post-mining goal of achieving wildlife habitat would most likely have a different equation than the post-mining land use for livestock grazing.

Partial Bond Release

The first alternative proposed is a partial bond release. Partial bond releases are commonly used by regulatory agencies. Part of the bond is released after the completion of significant portions of site reclamation. This includes activities such as reshaping and regrading or replacement of topsoil. Partial bond release can be as much as 80 percent or more of the total reclamation bond. The same concept can be applied to the revegetation portion of the bond. It is proposed that quantitative sampling occur after three and/or five years. If the vegetative characteristics measured fall within specified confidence levels of regression developed for that particular area and land use, part of the bond would be released. If this occurred after three years, 30 percent of the bond would be released or after five years, 50 percent of the bond would be released.

The major problem that may occur is that the revegetation does not achieve the ultimate goal established and there are not adequate funds for the area to be reseeded or otherwise treated. Partial release of bond in no way releases the mining company from its responsibility to ensure successful reclamation. It simply allows a company to regain a portion of its reclamation budget for doing a good job, which should encourage effective reclamation. Also for most companies the loss of the bond is not as important as the ability to obtain future mining permits. Issuance of permits may be denied if the mining companies do not demonstrate responsibility for their activities. Finally, failure to achieve the goals should be a rare occasion provided the trend lines are properly built. The precedent for partial bond release for completing specific reclamation functions such as topsoil replacement etc. has already been established. What is proposed is simply an extension of that process.

Early Bond Release

The second alternative is to provide full bond release after four to five years. This would be based on quantitative data showing that a positive trend has been established for a selected vegetation characteristic(s) and that the goal after 10 years would be reached if the trend continued. This approach would be less desirable since a release of bond could be equated with final success. While predictive data may provide a specific degree of confidence that the reclamation goal should be met, many land managers may not be willing to accept that specified risk. However, this alternative is still far superior to not having any well defined or quantifiable goals as is too often done in the industry currently.

CONCLUSIONS

The development of interim goals should enhance the bond release process. It would provide for greater continuity of personnel involved during the bond liability period. This should decrease problems associated with goals that had been agreed upon by both parties and should encourage greater trust between mining companies and regulatory agencies. Early or partial bond release should also enhance mineral development since money would be available sooner for use in other ventures. Finally and most importantly, it should lead to better reclamation by providing a more readily reachable goal. Long term goals are often not the primary emphasis of a company. Efforts to achieve those goals, particularly if they involve the expenditure of funds, may not be adequate. If the goal can be achieved in a shorter period of time, greater emphasis will be placed on the efforts to ensure bond release.

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